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Guides and Checks on Water Works Operation

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Presented on Oct. 30, 1945, at the Illinois Section Meeting, Chicago, Ill.

EVERY golf course has its "par" and every confirmed golfer his "handicap." The object of both is to improve the player's performance.

In the water works field the major holding companies have developed a system of yardsticks or checks upon the operations of their respective properties, individually adapted to the variations in service conditions, equipment and other facilities available for the service. These checks undoubtedly pay dividends for those companies and are an important part of the holding companies' service to their operating properties. However, but a very small percentage of all the water works systems in the country are under holding company operation and it is for the purpose of providing some general yardsticks for the large number of independently operated systems that this discussion is written. These yardsticks must necessarily be general but material deviations from the general range should flag the operator's attention and will usually indicate the desirability of investigating the causes for the lack of conformity. In most cases this will result in improved operation.

Starting with the widest generalities, it may be stated that the over-all number of employees in the operating and maintenance departments of the average water works will be within the range of one employee for each 800 to 1,200 population for cities of about 25,000 population, becoming less with greater populations and usually averaging one employee to each 1,500 to 2,000 of population for cities in the million population bracket. Obviously individual cities are affected by remote and widely scattered sources of supply, pumping stations, purification plants, etc., but the above figures are sufficient to indicate a very general range in total personnel.

Water works revenues in other than the more arid sections of the country normally range from $5.00 to $7.00 per capita per year. Operating expenses other than depreciation normally average approximately $2.00 per capita, with a range of from $1.25 to $3.00 per capita. The investment in property will average around $70 per capita and the annual depreciation charge will vary from approximately 75¢ per capita average for private water works to $1.25 per capita on municipally operated water works where the retirement reserve is largely utilized for new construction.

From these generalizations more specific reference will be made to some items of water works operation and their costs in which economies can most frequently be effected.

Pump Efficiency

Too few operators have information relative to the operating efficiency of their pumping equipment or what constitutes efficiencies practicable of attainment. In recent years there has been a noticeable trend toward motor-driven centrifugal pumping equipment, with which the following discussion is concerned.

Deep Well Turbines

Deep well turbine pumps are most frequently of low efficiency, due to the fact that they are usually installed from 100 to 300 ft. below ground surface, are out of sight and costly to remove for inspection. Over the years, however, they have been developed to a high degree of reliability.

It is now practicable to secure new equipment of this type in capacities of 700 gpm. and upward, which will operate at from 67 to 70 per cent or higher wire-to-water efficiency. It is the author's belief, based upon personal observation, that a large proportion of deep well turbine equipment is operating at so low an over-all efficiency that its replacement is warranted. On a recent investigation of a water supply which had three deep wells in the Chicago area, efficiency tests showed that all three pumping units had over-all efficiencies of less than 50 per cent. One unit, having a 1,000-gpm. delivery at a 140-ft. head, and testing 43 per cent, was removed from the well for inspection. It was found that the pump was badly worn and that some of the shaft bearings and column protector pipe were in poor condition. The defective bearings, shafting and pipe were replaced and new pump bowls purchased, involving a total expenditure of approximately $1,100. The saving in power due to the more efficient unit amounted to about $950 per year, sufficient to pay about 85 per cent annual return on the investment in the new unit. It would have been possible to purchase a new set of bronze pump bowls without the shafting and pipe for this unit for $535, and to increase the over-all efficiency from 43 to 68 per cent. The cost of the new bowls alone would have been fully recovered in about eight months' operation with the higher efficiency unit.

The pump bowls in at least one of the other wells are scheduled for replacement the next time the pump is pulled for any reason. In the meantime, the new, more economical unit is performing the major part of the pumping.

In another northern Illinois city two deep well 600-gpm. turbines, operating at approximately 250-ft. head, were recently tested. The wire-to-water efficiencies were 40.6 and 37.2 per cent respectively. One of these units is now

being replaced with an entirely new 1,000-gpm. unit with a guaranteed over-all efficiency of 67.5 per cent. The total cost of the motor, pump and 300 ft. of discharge column and shafting was $7,100. The saving in power will pay for the entire cost of this unit in a little over two years' time. The old unit is being rehabilitated for use as a spare.

As a check upon the efficiency of operation of deep well turbines, it may be stated that the average deep well turbine installation should use somewhere between 450 and 500 kwhr. per mil.gal. pumped 100 ft. high. Each 5 per cent loss in efficiency, with power purchased at 1¢ per kwhr. and assuming substantially continuous operation, will cost approximately $150 per year per million gallons pumped 100 ft. high. The correction of but a 5 per cent loss in efficiency will usually pay at least 25 per cent return on the cost of new bowls or the rehabilitation of the old equipment.

From the above, the following conclusions are indicated:

1. All deep well turbines should be frequently checked for wire-to-water efficiency.

2. Every deep well turbine should be carefully tested for efficiency prior to pulling the pump for inspection or other purpose.

3. Every deep well turbine installation should be so piped and wired that the water delivered and energy used can be measured on the individual installation.

4. Every deep well turbine installation should be provided with means of measuring water levels. These measurements should be made at frequent intervals and the data recorded.

5. Whenever the wire-to-water efficiency falls below 60 to 65 per cent it will usually pay to overhaul or replace the pump bowls if the unit is operated any large proportion of the time.

Horizontal Centrifugals

The observations made with respect to deep well turbines apply equally well, although usually with somewhat less force, to horizontal motor-driven centrifugal pumps. Certainly any centrifugal pump, which has been in continuous service for more than ten years and which is being used for "base load," is under suspicion as being uneconomic unless shown otherwise by test.

Table 1 shows the approximate over-all efficiencies which it is practicable to obtain with modern pumps of this type when operating against a 200-ft. head.

As compared to the above efficiencies four centrifugal units averaging 1.5 mgd. in capacity, which were recently tested in an Illinois water plant, had over-all efficiencies of 55.2, 41.3, 46.5 and 49.7 per cent respectively. The 55.2 per cent efficiency unit was of course the one most used. By installing one complete new unit of high efficiency, at a cost of less than $2,000 for motor and pump, to do most of the pumping, and by retaining the other inefficient units for reserve, it was possible to reduce the power cost by $600 per year, a 30 per cent return on the investment.

In general it can be stated that any centrifugal pump with a capacity of more than 4 mgd., which is performing with less than 70 per cent over-all efficiency, is uneconomical and should be repaired or replaced if the pump is to remain in continuous service. Complete new pumps and motors in sizes up to 10 mgd. and normal operating heads are available at a cost averaging about $500 per mil.gal. pumped 100 ft.

TABLE 1

gpm.	Approx. Over-all Eff., %	Annual Cost of Power @ 1¢/kwhr. Operating 75% of Time	Approx. Price of Pump and Coupling for 200′ Head	Annual Cost of 5% Loss in Eff. @ 1¢/kwhr.	Power Saving as % Return on Cost of New Pump and Coupling, %
700	65	$ 2,600	$ 370	$ 200	55
1,400	70	4,920	470	350	74
2,100	73	7,100	600	485	81
2,800	76	9,000	750	590	79
3,500	78	11,000	900	700	76
4,200	79	13,000	1,050	830	79
4,900	79	15,300	1,550	960	62
5,600	79	17,500	1,800	1,100	61
6,300	80	19,400	1,900	1,200	63
7,000	80	21,500	2,050	1,345	65

high. A new pump and motor will earn approximately 15 per cent on the investment as compared to an old unit that is 5 per cent less efficient. Assuming that the motor can be used, and only the pump discarded (which is usually practicable), the money expended for the pump alone would produce approximately 50 to 75 per cent return by operating at only 5 per cent better efficiency than the old pump.

In general, any pump in the 1- to 3-mgd. capacity range is uneconomic for regular service if its over-all operating efficiency is less than 60 to 65 per cent or, expressed in another way, if it uses more than 500 kwhr. per mil. gal. pumped 100 ft. high.

Similarly, any pumping unit in the 6- to 10-mgd. capacity range, which is in regular service and which is operating at less than 70 to 75 per cent overall efficiency, or approximately 475 kwhr. per mil.gal. 100 ft. high, is uneconomic.

The above statements do not mean that all equipment of low efficiency should be replaced. Such equipment is substantially as good as the more efficient equipment if operated only on peak or fire requirements. Its replacement is justified only when operated enough hours so that the saving in power used exceeds the interest and depreciation on the cost of the new unit. If its use becomes relatively continuous a smaller loss in efficiency will finance the replacement. Expressed in another way, if the base-load pumping units are maintained of high efficiency, the less efficient units can usually be economically retained as reserve units for long periods.

Meter Reading

There is a wide range in the costs of meter reading in water works systems. The general average cost of meter reading varies between 5¢ and 7¢ per reading. There are many instances where the cost in cities using outside settings is as low as 3¢ and occasionally one is found where the cost is as high as 13¢. A well-operated private plant in a southern city has averaged 1.8¢ per reading over the last five years. In that plant two meter readers, each with an assistant to remove and replace meter box covers, read 18,500 meters each month—an exceptional performance. The difference seems to lie partly in the amount of gossip the meter

reader dispenses and accumulates along the route. The manager of one large operating company advised that the principal difficulty that his company experienced in employing girl meter readers was the time lost through gossiping with the consumers and in negotiating "refreshments" offered to them. He reported that this was eventually corrected by bonus incentives for increased number of readings and decreased errors in reading. Meter reading is essentially "piecework" on which careful route-planning and study can set a standard for each system.

Billing

The handling of billing and collections, assuming an average use of modern accounting equipment, should be done with one employee for each 1,000 bills more or less per month. Some systems handle double this number per employee. In the system cited above for its meter reading performance, a force of seven girls handle the billing and accounting for the 18,500 monthly accounts, an average of 2,650 bills per employee.

Hydrant Repairs

Analysis of the records of a considerable number of cities discloses that the annual expenditure for hydrant repairs will vary from $1.75 to $4.00 per hydrant, with the general average about $2.50. In one city, where there was a nine-year average cost of hydrant maintenance of $8.05 per year per hydrant, investigations showed that the use of hydrant wrenches was substantially unrestricted. Every street employee, fireman, contractor, street flusher and many others had a wrench and used it freely. Further analysis showed that in this city there was an annual replacement equivalent to 70 hydrants for each 10,000 installed, as compared to a general average figure of 25 to 35. Bad practice regarding usage of hydrants adversely affected both the annual maintenance cost and the life of the hydrants.

Meters

The big difference in unaccounted-for water recorded by municipalities is believed to be most largely due to: (1) the character of meter maintenance, and (2) the sizing of meters.

In the normal city, with meters properly proportioned to the service, over 99 per cent of all meters are 1 in. and under. Recently, in a comparatively small, wholly residential town, where an investigation disclosed more than 30 per cent of the pumpage unaccounted for, it was found that the size of meter was determined either by the size of the service or the customer's request. There was no graduated scale in minimum charges. It was found that 2.5 per cent of all meters were larger than 1 in. and that 6 per cent of the meters were 1 in. and larger. Illustrative of the laxity in meter sizing and its effect upon unaccounted-for water is a fountain in the municipal building which continuously runs at a rate of more than 1 gpm. The municipal building was served through a 2-in. meter which failed to register this amount flowing through the fountain and which began to register only when another fixture was opened to nearly full flow. This 2-in. meter was replaced by a 1-in. and in the first month it recorded 30,000 gal. more than the 2-in. meter had been registering.

Investigation further disclosed that there were many 2-in. meters on lawn "gang sprinkler" installations which were rarely used but which allowed the

normal household requirements to slip by without registration. One residence even had a 3-in. meter and there were many 1½- and 2-in. meters on residences. It was found that the 1½-in. meters averaged two-thirds more water registration than the 2-in. meters.

Obviously where there are large seasonal requirements there should be two meters—one a small household meter and the other for large requirements—each bearing its proper minimum or service charge.

Meter Registration

It has been ascertained that from 12 to 15 per cent of all water used is at rates of 0.25 gpm. or less. Kuranz (1) found that only about eleven of the 52 cities tested their new meters on a flow as low as 0.25 gpm. Observations made by the author (2) showed that of 221 meters tested in eight different plants, 53 meters selected from service at random failed to register at all when tested at a rate of 100 gpd., and 44 more registered less than 50 per cent of the water passing through them at that rate. In one city in which the unaccounted-for water was 42 per cent, not a single meter of twelve tested registered at 100 gpd. It is the author's opinion that meter testing is scarcely worth doing at all unless the meters are adjusted to catch flows of 0.25 gpm. or less.

Meter Repair Costs

The frequency of meter repairs and the procedure by which meters to be tested are selected vary widely in different cities, presumably reflecting the experience of the various cities and the variations in waters. In the records of ten cities recently studied, an average of 12 per cent of the total number of meters were repaired each year. That would indicate a general average of a meter being thoroughly overhauled once in eight years. The weighted average cost of meter repairs in seven of these cities for which the costs were available was approximately $1.70 per meter, based upon approximately 25,000 meters repaired.

In a recent check on a small private water company in which 484 meters were tested, the average over-all cost was $1.26 per meter, divided equally between labor and materials.

Kuranz (1) records figures from approximately 50 plants from which it is computed that the average time for meter repairs in 42 cities was one hour and 24 minutes and the average cost of repair parts 31¢. Deducting this 31¢ from the total for labor and materials of $1.70 above referred to would leave $1.39 as the labor cost. This $1.39 spread over Kuranz' average time of one hour 24 minutes per meter would give a labor rate of $1.00 per hour, indicating a good agreement in the data.

Repairing meters to catch small flows pays dividends. The city accounting for but 58 per cent of its pumpage fifteen years ago (previously referred to) has 30,000 meters. Last year it was paid for 89 per cent of the pumpage—adjusting meters so as to catch small flows was the principal difference. In another city the meters in one-third the system (about 15,000 total) were tested and adjusted to catch small flows in a single year. The results were so impressive that the other two-thirds were then similarly adjusted. That city now gets paid for 90 to 92 per cent of the pumpage. From the above it is concluded that:

1. It is usually practicable to measure and receive payment for 85 per cent or more of the pumpage.

2. The principal factors in reducing "Unaccounted-for water" are believed to be improved meter repair and meter adjustment to catch low flows.

3. Every meter that comes to the shop should be adjusted so as to register accurately all flows at least as low as 0.25 gpm.

4. The average cost of meter repairs is probably between $1.25 and $1.75 per meter. Assuming that as an average 12 per cent of the meters are repaired per year this is equivalent to from 15¢ to 25¢ per year when spread over the total number of meters installed.

5. The total cost of operation and maintenance of more than 500,000 meters in a number of larger cities for which records are available is approximately 50¢ per meter. This includes routine testing, cleaning and maintenance, as well as repairs.

6. Proper sizing of meters is important. This should be determined solely by the utility.

7. Service or minimum charges should be so graduated as to make over-sizing unattractive to the water consumer.

Car and Truck Operation

There is a wide divergence in the use of cars on various water works systems. It would appear that this use, if properly regulated, should be a reflection of the mileage of mains in the system and the population served.

L. A. Geupel (3) submitted data regarding automobile use in 22 cities with populations varying from 100,000 to 200,000. The average population was approximately 140,000. The average number of cars and trucks in these systems was 27 per system or a weighted average ratio of one car per 5,300 population. The average miles operated per year per 1,000 population was 1,870.

An analysis made in the author's office of fifteen cities varying in population from 225,000 to 1,000,000 showed a weighted average of 8,000 population per car and an average mileage of 1,120 per year per 1,000 population. In one city which was investigated in detail, there were substantially no restrictions on the use of cars and all cars were stored in the private garages of the men using them. In this city there was an average of one car for each 4,500 people and the average mileage per 1,000 population was 2,860; the annual mileage per mile of main was 1,310, a figure two and one-half times the general average; the average annual cost per mile of main was $83.50, as compared to a general average of $28.20; and the annual cost per capita was 18¢, as compared to a general average of 6¢.

In general it is believed that a reasonable mileage for cars and trucks in a water works system is best indicated by the mileage of mains which they are called on to service and a general figure of 500 miles of travel per year per mile of mains in the distribution system is reasonable of attainment.

Distribution System Operation and Maintenance

This item, excluding services and meters, is primarily a reflection of the mileage of mains in the system and the size of the mains, although if there is a large amount of material other than cast iron it may also be affected thereby. In general, the cost of distribution system operation and maintenance, exclusive of services and meters, in well-maintained systems averages about $12 per inch diameter per mile of pipe per year.

TABLE 2

Condensed Monthly Operating Statement
September 1944

	September		Totals to September 30	
	1944	*1945*	*1944*	*1945*
Water Revenue				
Residential Metered				
Commercial Metered				
Industrial Metered				
Municipal Metered				
Public Fire Hydrants				
Private Fire Hydrants				
Sprinkler System				
Total Water Revenue				
Water Operating Expense				
Operations				
Source of Supply				
Electric Power Purchased				
Steam Pumping				
Purification				
Total Production Expense				
Transmission and Distribution				
Commercial Expense				
General Expense				
Total Water Operating Expense				
Maintenance Expense				
Pumping				
Purification				
Total Production Maintenance				
Transmission and Distribution Expense				
General				
Total Maintenance Expense				
Total Operating and Maintenance Expense				
Taxes other than Income				
Total Water Expense				
Operating Income				

Operating Statistics

Mil. Gal. Pumped to Mains				
Mil. Gal. Metered				
Mil. Gal. Not Metered				
% Unmetered to Pumpage				
Number of Consumers				

Operating Records

Every water utility should have a standard form of report. This report should be prepared monthly so as to show current costs and efficiency in comparison with those of the corresponding month of the previous year. The annual report does not serve this purpose adequately. The post mortem review of operations, too long dead, which it records, simply embalms inefficiency, the correction of which requires prompt knowledge of its existence.

An example of what is believed to be a minimum in monthly reports is shown in Table 2. This is usually expanded to show details.

Municipal utilities would benefit, as those privately owned have benefited, from the adoption of the Standard Classification of Accounts prescribed by the National Association of Railway and Utility Commissioners.

Conclusions

The foregoing illustrates some of the checks which can be readily applied to the ordinary water works operations. It is hoped that those who read this discussion will be moved to analyze their own operations, compare them with these very general standards, and establish "par" for each operation in their own plants.

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DISCUSSION—*James E. Kerslake*

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In view of the fact that matters relating essentially to purification were not included in Mr. Howson's excellent paper and because the writer's experience has been primarily limited to the operation of a purification plant, the discussion here will be limited to this subject.

Pumping Efficiency. Pumps should be operated at their maximum efficiency. In balancing the flow through the plant, it is at times more convenient to operate pumps above or below the point of maximum efficiency, rather than running them at maximum efficiency and balancing with the clear well. Running at the maximum point generally involves more pump changes. Wire-to-water efficiency should be checked daily to make sure that maximum efficiency is being obtained. If running at the maximum efficiency involves too frequent pump changes for good operation, a more detailed study should be made to determine whether or not sufficient savings can be made to warrant replacement of pumps with those designed to operate more efficiently at the desired rates.

Meters. Meters should be checked at regular intervals to make sure that they are recording correctly. A rapid daily over-all check can be obtained at a water purification plant by calculating the total output of filtered water from the time, filter rate and number of filters operated. This will also indicate whether or not the filter rate

controllers are recording correctly. A hook gage and stop watch can be used to check the filter rate.

Heating. In checking the cost of heating, a survey should be made and a figure, in terms of degree days, set up as a guide. In Milwaukee, steam for heating the water purification plant is obtained from the North Point Pumping Station, and the pounds of steam per degree day is used as a guide. Thermostats should be installed at various points and the various sections of the building should be heated according to use. Heat losses should be prevented by pipe covering, storm windows, etc. There are thermostats on the market which can be attached to individual radiators, if required.

Safety. If the plant is large enough, a safety committee should be set up. If not, a plant representative should be on the water department safety committee. This committee should meet at regular intervals to hear and discuss suggestions and to receive detailed reports of all accidents. When the safety program is first inaugurated, it will be found that additional expenditures will be necessary to carry out the worthwhile suggestions which will be offered. This expense will decrease as time goes on, and will be compensated for in the long run by a decrease in the number of accidents.

Advantages of Cement Linings for Cast-Iron Pipe

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Presented on Nov. 6, 1945, at the North Carolina Section Meeting, Charlotte, N.C.

THE two principal advantages of cement linings for water pipe are: (1) the increase in carrying capacity when the pipe is new and the maintenance of its original capacity as it gets older; (2) the mitigation of tastes, odors and red water difficulties. This paper is limited to a discussion of the first advantage, namely, the increased carrying capacity.

In order to understand the financial advantages of using cement linings it is necessary to have some knowledge of certain hydraulic phenomena that enter into the problem. It is a fact that when water moves through pipe a certain amount of friction is developed between the water and the inside of the pipe. The result is that, as the water travels along the pipe, some of the energy imparted to it by the pump is consumed by friction, resulting in a loss of pressure. The amount of friction so developed is the criterion by which the size of pipe and the amount of power to be used for pumping purposes are determined. When a given amount of water is to be transported the total amount of friction developed depends on the size and length of the pipe and the condition of its interior.

As early as 1775, Chezy, a French engineer, recognizing the fact that the rate of flow of water through pipe lines with identical diameters and lengths was not a constant, proposed the use of a formula for determining pipe capacity. His formula was difficult to use because it contained a coefficient that varied with each set of circumstances surrounding the particular project under consideration. This formula has, to all practical intents and purposes, been superseded (since about 1905) by the Hazen-Williams formula:

$$V = Cr^{0.63} s^{0.54} 0.001^{-0.04}.$$

This formula was developed empirically from results of tests on a number of water lines throughout the United States. The coefficient C in this formula is intended to reflect the condition of the interior of the pipe. The other values in the formula have to do with length, loss of head and size of pipe. In this paper we are concerned only with the value of C. According to Hazen and Williams the value of C for new hot-coal-tar-dip cast-iron pipe is 130. Tables published in connection with this formula indicate that this value falls off with time and varies with different sizes of pipe. For example, according to the Hazen-Williams tables, 12-in. pipe reaches a coefficient of 100 at the end of seventeen years, and a coefficient of 80 at the end of 37 years, whereas a 36-in. pipe reaches a coefficient of 100 in 20 years and a coefficient of 80 in 44 years. Since the coefficient is a direct measure of the amount of water delivered under a given set of conditions, this means that at the end of 37 years a 12-in. pipe would deliver about 60 per cent as much water as a new pipe.

Engineers recognized that, while falling off in carrying capacity was a common experience in certain parts of the country, there were places where there was either no change, or only a very slight change in carrying capacity, depending on the character of water conveyed. As a precautionary measure it became common practice for engineers to assume a Hazen-Williams coefficient of 100 for design purposes regardless of water characteristics. As a result of this, in those places where tuberculation did not occur the customer received better service, exemplified either by higher pressure or lower pumping costs. On the other hand, in those places where tuberculation did occur the reverse was the case, and as time went on pressure either became less or power costs more.

European engineers attempted to develop linings to prevent tuberculation a great many years ago and about 80 years ago an effort was made in this country to produce a pipe that would not tuberculate. The result was the development of Phipps Patent pipe, which consisted of a thin steel shell with thick ($\frac{1}{2}$-in. plus) cement-mortar lining and coating. This type of pipe solved the problem of tuberculation, but was difficult to maintain because of its low beam strength and the high rate of joint leakage and because of the difficulty of making taps. Furthermore, when the outer shell cracked, corrosion very quickly took out the thin steel shell. In spite of the drawbacks of this kind of pipe, some of it is still in service after more than 70 years, and cement-lined service pipes developed in New England many years ago are still commonly used in that part of the country.

In 1921 the first effort was made to provide cement linings for cast-iron pipe. This was due originally to the efforts of Dr. J. E. Gibson of Charleston, S.C., and the management of the American Cast Iron Pipe Company. Cement-lined cast-iron pipe has now been in service long enough to demonstrate the fact that it has a continued high flow coefficient. Tests by the staff of the Cast Iron Pipe Research Association, as well as others, prove this point. Notable results were obtained at Charleston, S.C., where tests made over a number of years indicate practically no loss in capacity during a 23-year period, in spite of the fact that a highly tuberculating water is handled.

Tests have indicated that less friction results when cement linings are used, even where non-tuberculating waters are found. For instance, a test made at Lincoln, Neb., on a new 36-in. hot-coal-tar-dip supply line showed it had a coefficient of approximately 135. A test on a new 36-in. cement-lined pipe installed at Corpus Christi, Tex., gave a value of 145. Since in both cases new pipe was tested, the principal difference had to do with the condition of the interior.

In order to demonstrate the economics of linings let us consider a case based on flow conditions that prevailed at Corpus Christi at the time flow tests were made and project them into the future. A 36-in. (nominal diameter) cement-lined pipe under test was carrying 8,290,000 gpd. in a line 74,400 ft. long. The Hazen-Williams coefficient determined by the tests was 145 and the loss of head was 16.8 ft. Also tested was a 20-in. tar-coated line that had been in service 29 years and it was found to have a coefficient of 102. (It is safe to assume that at the end of one more year this coefficient would have been 100.) Assuming for the moment that the demand did not increase and assuming a pumping cost of 5¢ per mil. gal. 1 ft. high, the annual cost of pump-

ing against friction head only if tar-dipped pipe were used (actual inside diameter 36.8 in.) would have ranged from \$3,140 per year when new ($C = 130$) to \$5,160 per year when the pipe had reached an age of 30 years ($C = 100$). In the case of cement-lined pipe the pumping cost for the first year ($C = 140$) would have been \$2,540 and would remain the same throughout the 30-year period. The actual saving for this period resulting from the use of a cement lining would therefore be \$48,300. As a matter of fact, in designing the pipeline the engineers, of necessity, have taken into account the growth of the community and the increased demand for water. It is highly probable that 30 years hence this line will be required to deliver 16 mgd. When this point is reached the annual cost of pumping this amount of water through a tar-dipped line would be \$33,400. The annual cost of pumping the same amount of water against the friction head in a cement-lined pipe would be \$17,130. The average annual saving in pumping cost between the cement-lined pipe and the tar-dipped pipe for the 30-year period amounts to \$8,435 per year. Capitalizing this at 4 per cent, we find it would be economical to invest \$210,875 in order to avoid the extra pumping cost. The actual cost of the lining at the present market price would be approximately \$40,000.

Another factor to be considered is that if tar-dipped pipe were used the head when the pipe was new would be 184 ft. and this would increase to 278 ft. at the end of 30 years when 16 mgd. were being pumped. On the other hand, with the same increase in pumping the head on the cement-lined pipe would increase from 180 to only 222 ft. This increased pressure means that if tar-dipped pipe were to be used a pipe of a heavier class would be required. It also means that leakage in the line would be increased.

Under certain circumstances in designing a pipeline the use of cement linings may make it possible to use a pipe of a smaller diameter than if tar-dipped pipe were used. To demonstrate this the author has made certain assumptions regarding capacities and growth, and has worked out the actual pumping cost for each five-year period from the time the pipe is installed until it has reached the age of 45 years. The computations are shown in Table 1. From this table it is evident that for the conditions assumed an 18-in. cement-lined pipe would result in lower cost for delivery of water than would a 20-in. tar-dipped pipe. In arriving at these costs only the power cost for pumping and interest and sinking fund on the investment have been taken into account. Other costs, such as the cost of pumps, motors, pumping station labor, etc., would be the same regardless of the size of the pipe. Table 1 also gives the costs for 16-in. and 24-in. cement-lined pipe operating under similar conditions. In both cases the annual cost is greater than that for the 18-in. cement-lined pipe, indicating that 18 in. is the economical size to use.

Table 1 has indicated the possibility of using a smaller size of pipe if cement linings are used—the economy being apparent from the time the pipe is first installed. In larger diameters the effect is not so apparent until an age of approximately 30 years is reached, as demonstrated in Table 2.

So far we have presented figures dealing only with large sized pipe that would be used for supply lines or for main feeder lines within a city. The argument of additional carrying capacity applies as well to minor distributors and to the smaller mains in

TABLE 1

Assumptions

Water demand of new pipe: 3 mgd.
Water demand 30 years later: 4 mgd., then constant.
Length of line: 20,000 ft.
Delivery pressure: 100 ft.
Power cost for pumping 1 mil.gal. 1 ft. high: $.05
Interest: 4%

Cost of pipe installed per foot:

in.	
16	$5.00
18	5.60
20 (tar-dipped)	6.00
24	7.50

Coefficient of cement-lined pipe: 140
Coefficient of tar-dipped pipe: In accordance with Hazen-Williams tables starting with 130.

20-in. Tar-Dipped

Period Covered *yr.*	Demand *mgd.*	*C*	Loss per 1,000 *ft.*	Total Head on Pump *ft.*	Million Gallons Pumped 1 ft. High	Power Cost per Day	Interest and Sinking Fund per Day	Power Cost Plus Interest and Sinking Fund per Day	Pump Cost for 5-yr. Period	Cumulative Pump Cost
0–5	3.083	125	0.93	119	367	$18.35	$13.40	$31.80	$58,000	$58,000
5–10	3.250	116	1.17	123	400	20.00	13.40	33.40	61,000	119,000
10–15	3.410	108	1.47	129	440	22.00	13.40	35.40	64,600	183,600
15–20	3.576	100	1.83	137	490	24.50	13.40	37.90	69,200	252,800
20–25	3.742	94	2.25	145	543	27.15	13.40	40.55	74,100	326,900
25–30	3.908	89	2.70	154	603	30.15	13.40	43.55	79,500	406,400
30–35	4.000	85	3.05	161	644	32.20	13.40	45.60	83,200	489,600
35–40	4.000	81	3.32	166	664	33.20	13.40	46.60	85,000	574,600
40–45	4.000	77	3.65	173	692	34.60	13.40	48.00	87,600	662,200

18-in. Cement-Lined

Period Covered *yr.*	Demand *mgd.*	*C*	Loss per 1,000 *ft.*	Total Head on Pump *ft.*	Million Gallons Pumped 1 ft. High	Power Cost per Day	Interest and Sinking Fund per Day	Power Cost Plus Interest and Sinking Fund per Day	Pump Cost for 5-yr. Period	Cumulative Pump Cost
0–5	3.083	140	1.25	125	385	19.25	12.50	31.75	57,900	57,900
5–10	3.250	140	1.37	127	412	20.60	12.50	33.10	60,300	118,200
10–15	3.410	140	1.50	130	444	22.20	12.50	34.70	63,300	181,500
15–20	3.576	140	1.65	133	475	23.75	12.50	36.25	66,100	247,600
20–25	3.742	140	1.80	136	510	25.50	12.50	38.00	69,300	316,900
25–30	3.908	140	1.94	139	543	27.15	12.50	39.65	72,300	389,200
30–35	4.000	140	2.02	140	560	28.00	12.50	40.50	73,800	463,000
35–40	4.000	140	2.02	140	560	28.00	12.50	40.50	73,800	536,800
40–45	4.000	140	2.02	140	560	28.00	12.50	40.50	73,800	610,600

16-in. Cement-Lined

Period Covered *yr.*	Demand *mgd.*	*C*	Loss per 1,000 *ft.*	Total Head on Pump *ft.*	Million Gallons Pumped 1 ft. High	Power Cost per Day	Interest and Sinking Fund per Day	Power Cost Plus Interest and Sinking Fund per Day	Pump Cost for 5-yr. Period	Cumulative Pump Cost
0–5	3.083	140	2.22	144	445	22.25	11.20	33.45	61,200	

24-in. Cement-Lined

Period Covered *yr.*	Demand *mgd.*	*C*	Loss per 1,000 *ft.*	Total Head on Pump *ft.*	Million Gallons Pumped 1 ft. High	Power Cost per Day	Interest and Sinking Fund per Day	Power Cost Plus Interest and Sinking Fund per Day	Pump Cost for 5-yr. Period	Cumulative Pump Cost
0–5	3.083	140	0.31	106	327	16.35	16.80	33.15	60,400	

the gridiron system, since, regardless of the size of pipe, there is less friction loss in cement-lined pipe than tar-dipped pipe. While it is true that the minimum size of pipe in distribution systems is usually established by some rule of an insurance rate-making body, the additional pressure available when

TABLE 2

Assumptions

Water demand of new pipe: 12 mgd.
Water demand 30 years later: 16 mgd.
Length of line: 20,000 ft.
Delivery pressure: 100 ft.
Power cost for pumping 1 mil.gal. 1 ft. high: $.05
Interest 4%
Cost of 30-in. cement-lined pipe: $9.80 per ft.
Cost of 36-in. tar-dipped pipe: $11.80 per ft.
Coefficient of cement-lined pipe: 140
Coefficient of tar-dipped pipe: In accordance with Hazen-Williams tables starting with 130.

Period Covered *yr.*	Demand *mgd.*	*C*	Loss per 1,000 *ft.*	Total Head on Pump *ft.*	Million Gallons Pumped 1 ft. High	Power Cost per Day	Interest and Sinking Fund per Day	Power Cost Plus Interest and Sinking Fund per Day	Pump Cost for 5-yr. Period	Cumulative Pump Cost
36-in. Tar-Dipped										
0–5	12.33	126	0.68	114	1,410	$70.50	$26.40	$96.90	$176,500	$ 176,500
5–10	13.00	118	0.84	117	1,520	76.00	26.40	102.40	187,000	363,500
10–15	13.67	109	1.06	121	1,650	82.50	26.40	108.90	198,500	562,000
15–20	14.33	103	1.28	126	1,810	90.50	26.40	116.90	213,200	775,200
20–25	15.00	97	1.57	131	1,960	98.00	26.40	124.40	227,000	1,002,200
25–30	15.67	92	1.90	138	2,160	108.00	26.40	134.40	245,500	1,247,700
30–35	16.00	88	2.14	143	2,290	113.50	26.40	139.90	255,000	1,502,700
35–40	16.00	84	2.32	146	2,340	117.00	26.40	143.40	262,000	1,764,700
40–45	16.00	81	2.48	150	2,400	120.00	26.40	146.40	268,000	2,032,700
30-in. Cement-Lined										
0–5	12.33	140	1.35	127	1,570	78.50	21.90	100.40	183,300	183,300
5–10	13.00	140	1.48	130	1,690	84.50	21.90	106.40	194,000	377,300
10–15	13.67	140	1.64	133	1,830	91.50	21.90	113.40	207,200	584,500
15–20	14.33	140	1.78	136	1,950	97.50	21.90	119.40	218,000	802,500
20–25	15.00	140	1.95	139	2,080	104.00	21.90	125.90	229,500	1,032,000
25–30	15.67	140	2.10	142	2,220	110.00	21.90	131.90	240,600	1,272,600
30–35	16.00	140	2.19	144	2,300	115.00	21.90	136.90	250,000	1,522,600
35–40	16.00	140	2.19	144	2,300	115.00	21.90	136.90	250,000	1,772,600
40–45	16.00	140	2.19	144	2,300	115.00	21.90	136.90	250,000	2,022,600

cement linings are used may easily be the measure of the difference between getting sufficient water to stop a fire at its inception and of being penalized by reduced carrying capacity to the point where what would normally be a small fire becomes a major conflagration. It is also a fact that where tuberculating waters are found the falling off in carrying capacity of smaller mains takes place at a faster rate than is the case with larger mains. This means that in a comparatively short time the capacity of tar-coated pipe is so reduced that replacement becomes necessary. The cost of cement lining, which insures carrying capacity for the life of the pipe, is much less than the cost of replacement, even though that replacement might be delayed for as much as 45 years. The long physical life of cast-iron pipe means little if its carrying capacity becomes impaired, and the logical way to prevent this impairment is by the use of cement linings.

Baffling Sedimentation Basins

By R. W. Hayden

Chemist, Suburban Water Co., Oakmont, Pa.

Presented on Sept. 14, 1945, at the Western Pennsylvania Section Meeting, Pittsburgh, Pa.

At the Suburban Water Company, Oakmont, Pa., low-lift pumps take the water from the river and discharge it over a cascade aerator. From the aerator the water runs into a down-flume in which lime, alum and chlorine are mixed with the water. This down-flume discharges the water into a mechanical mixing basin (Mix No. 1) approximately 24 ft. square. The detention period of this basin is 25 minutes at a rate of 3 mgd. Coagulation takes place in this basin and the water then flows into a sedimentation basin (Basin No. 1) where primary settling takes place.

At the entrance to Basin No. 1 is a perforated wooden distribution flume which extends the entire width and depth of the basin. Basin No. 1 is unbaffled and has a detention period of one hour at 3 mgd. It is 48 ft. long and 32 ft. wide. The water leaves the sedimentation basin through a perforated surface flume, 2 ft. wide by 3 ft. deep, and enters Mix No. 2 through a down-flume 2 ft. × 3 ft., where carbon is added during taste and odor control periods.

Mix No. 2 is the same size as Mix No. 1. The paddles in both mix basins travel at a rate of 2 rpm. The water leaves Mix No. 2 through a surface flume 2 ft. × 3 ft. Ammonia is added to the water in this flume to assist in maintaining residual chlorine in the system. The water in this flume is then divided and enters a second sedimentation basin (Basin No. 2) through two perforated surface flumes, 2 ft. × 3 ft.

Sedimentation Basin No. 2 consists of two separate and parallel baffled basins, each with a total length of 80 ft. and a width of 24 ft. All basins are 20 ft. deep. The detention period in the No. 2 basin is two hours at a rate of 3 mgd. There are two underpass and one overpass baffles which are approximately 20 ft. apart. The water leaves this basin through a surface weir flume from which it flows to the filter gallery. Secondary carbon is added at this point.

The plant was designed to handle 3 mgd. During the last few years of wartime demands it has had to handle an average of 3.5 mgd., with peak loads as high as 4 mgd. For 3 mgd. or less coagulation and sedimentation take place efficiently, but for more than 3 mgd. there is a problem.

Coagulation in Mix No. 1 is good under all operating conditions. Water entering Basin No. 1 at 3 mgd. or less is well prepared and will drop 60 per cent of its turbidity. Waters of moderate turbidity at a 4-mgd. rate will lose 30 per cent. When this occurs the floc in Basin No. 1 is of a light, fluffy snowflake nature, which, on jar test, will settle the large flakes rapidly but which leaves considerable small floc present which is slow to settle. During high

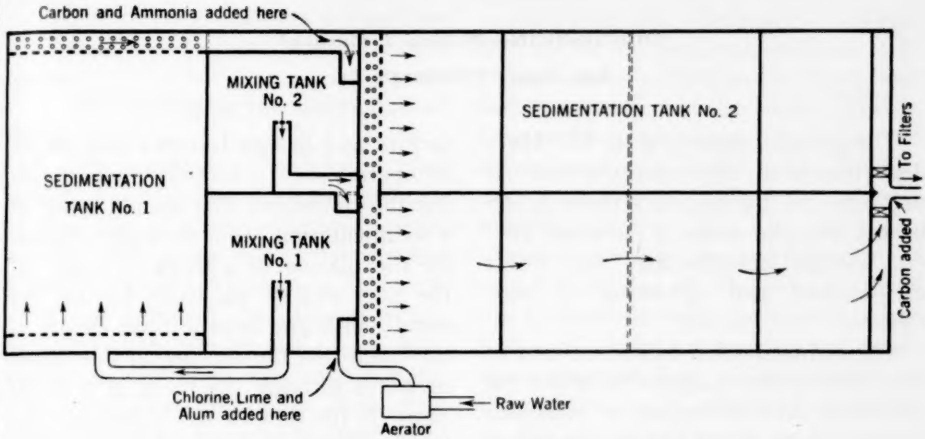

FIG. 1. Flow Diagram for Suburban Water Co.

rates of flow the floc leaving Basin No. 1 is apparently broken or compressed by the turbulence of the water flowing through the flume to Mix No. 2.

The floc generated in Mix No. 2 is of a small dense nature, which, on jar test, settles rapidly and leaves clear water. During pumpage of 3 mgd. or less this floc is transmitted to Basin No. 2 in good condition, but during high pumpage this floc breaks down on flowing through connecting flumes.

At a rate of 3 mgd., water entering Basin No. 2 has a dense floc, which increases in size as it flows through the basin. This floc settles well and gives a filter influent of relatively low turbidity.

At rates above 3 mgd., water entering Basin No. 2 has a very small floc, which slowly increases in size as it flows through the basin. In the first 40 ft. there is little or no reduction in the turbidity, even though the water has had to travel through an underpass baffle and return to the top of an overpass baffle. In the next 40 ft. the water flows through another underpass baffle and rises to the surface weir flume connecting to the filter influent. It is in this part of the basin that most sedimentation takes place and gives a filter influent of moderate turbidity.

Turbidity Data

Rate	*Raw Water*	*Sedimentation Basin No. 1*	*Sedimentation Basin No. 2*	*Filter*
mgd.	*ppm.*	*ppm.*	*ppm.*	*ppm.*
2.7	40	11	7	4
3.0	55	20	16	7
3.4	40	15	12	7
3.8	40	24	20	10
4.0	25	20	20	9

From this table, turbidities on the filter do not seem excessive but they have increased over 100 per cent at high rates of pumpage. No complete data were available during periods of high turbidity; however, it is known that with raw water turbidities of approximately 500 ppm. and high pumpage the turbidity on top filter was 22 to 25 ppm.

The Suburban Water Company is interested in improving the efficiency of its present system; it also anticipates some changes to meet increased postwar demands.

DISCUSSION—*William J. Murdoch*

San. Engr., Pittsburgh, Pa.

The problem presented by Mr. Hayden gives us an opportunity to discuss not only the baffling of sedimentation basins, but also some of the other general design features that may affect the control and operation of such basins.

The sedimentation basin is a unit of the water plant designed to allow the quiescent flow of water at velocities low enough to permit the sedimentation and removal of suspended particles from the water. In most plants this basin is preceded by units to which chemicals are applied to facilitate the sedimentation process.

The principles of sedimentation are fully discussed in many text books and publications. Briefly, some of the conditions that affect the sedimentation of particles suspended in water are as follows:

1. Influence of gravity.
2. Size, shape and specific gravity of settling particles.
3. Viscosity of water.
4. Currents in the water.
5. Design and operation of the settling basin.
6. Tendency of particles to coalesce or coagulate.
7. Temperatures of air and water.
8. Other miscellaneous phenomena.

Many of these conditions present complex problems that are beyond the scope of this discussion. It is believed advisable therefore to restrict this discussion to the more fundamental factors affecting sedimentation.

Every water plant operator should have a general knowledge of the purpose of each unit of his plant and of the factors and design features that affect its operation. To simplify understanding the conditions that should exist in a sedimentation basin we might visualize the placing of a block of water in the inlet end of the basin having the same width and approximate depth as the basin and the moving of this block of water through the basin at a given rate. If the flow of water through the basin could be maintained in this manner, each unit volume of water would have the same velocity of flow and the same period of detention, and each particle of suspended material would be subject to uniform conditions. To obtain such a flow is obviously very difficult, if not impossible. Even though the water were introduced uniformly the flow would be affected by the influence of the sides and bottom of the basin, varying densities due to temperature, concentration of solids, entrained gases and such other factors.

To determine whether a basin and its related facilities are designed to produce satisfactory flow conditions, observations and study should be made of each functional part. The elements that might be considered are as follows:

1. The outlet design of the coagulation or mixing basin.
2. The velocity of flow from the coagulation or mixing basin to the sedimentation basin.
3. The layout of piping leading to the basin.
4. The distribution of the incoming water across the width of the basin.
5. The baffling at the inlet end of the basin.

6. The physical features throughout the basin and between the individual basins.

7. The baffling at the outlet end of the basin.

8. The method of collection and withdrawal of water from the basin.

This list of design features might well be used for a guide as the problem presented by Mr. Hayden is analyzed.

In this problem the plant is being operated at an average rate of 3.5 mgd. and at a maximum rate of 4.0 mgd. The water flows through a 20-in. pipe from the mixing basin to the first sedimentation basin. The velocities of flow in this pipe are 2.5 and 2.8 fps. at the average and maximum rates respectively, and will probably be greater in certain areas of the pipe at the points where 90-deg. bends are located. This rate of flow is excessive and a larger inlet pipe is believed necessary.

The inlet pipe in this case discharges into the end of the basin at a point near the center and at the elevation of the flow line. The purpose of a properly designed inlet is to distribute the water uniformly across the width of the basin, this being particularly important for basins small in length. Better distribution of the incoming water would be effected if multiple inlets or some similar arrangement were provided. The installation of a piping arrangement to obtain uniform flow from each of more than one inlet presents a problem that must be given careful consideration. The providing, let us say, of three openings of uniform size and spacing does not necessarily insure equal flows from each opening. The hydraulics of flow through multiple openings leading off one line must be studied and the location and sizes of these openings arranged to obtain an equalization of flow.

Following the discharge of water into the basin, the next problem is to obtain uniform distribution throughout the cross-section of the basin. This is frequently accomplished through the use of perforated baffle walls. In this case a perforated baffle wall has been installed having 225 2-in. openings. The area of these openings is equivalent to 4.9 sq.ft. and the theoretical velocities of flow through the openings are 1.12 and 1.26 fps., at average and maximum rates of flow. This velocity of flow will probably be much higher due to the concentration of the incoming water at one point, resulting in short circuiting and the passage of the water through only a limited number of openings. Since the arrangement and design of the baffle wall are fairly conventional, its efficiency would be greatly increased with better inlet distribution.

The sedimentation basin designated No. 1 is 29 ft. 6 in. × 45 ft. 4 in. in plan and 20 ft. deep, and has a capacity of approximately 200,000 gal. The theoretical periods of detention are approximately 1.2 and 1.33 hours respectively at the average and maximum rates of flow. This basin will effect some removal of suspended material, particularly with heavy concentrations, but cannot be expected to accomplish entirely satisfactory results due to relatively short periods of detention, to a greater depth than is generally desirable for a basin of this size and to inlet and outlet conditions.

The outlet end of the basin consists of a perforated trough having approximately the same area of openings as the baffle at the inlet end. The velocity of flow through these openings will have a tendency to lift the light particles suspended in a certain depth zone extending beneath this trough and carry

them into the second mixing basin. The floc, being large and fluffy in character, will be destroyed at this point. The excessive velocities of flow through the bends existing in the path of flow between these basins will also cause the floc to break into smaller particles.

The existence of a mixing basin at this point in the path of flow is unusual and means that the water passes through another coagulating and sedimentation process similar to the original. In the routine operation of the plant activated carbon is fed into the second mixing basin. The mixing at this point results in the development of the floc once again due to the flocculent characteristics developed by the action of mixing.

The flow from Mixing Tank No. 2 enters each section of Sedimentation Basin No. 2 through 12-in. openings at velocities of flow of 3.5 and 3.9 fps., at average and maximum rates of flow respectively. This velocity is excessive and the floc will undoubtedly be destroyed again. Larger inlet openings are very necessary at this point. Here again inlet conditions are not satisfactory. The one 12-in. opening is on the direct line of flow whereas the other receives the flow after it passes through two 90-deg. bends. This condition will result in an unbalanced flow. These two inlets enter each of the two basins at adjacent corners, failing again to give satisfactory distribution across the inlet end of the basin. The perforated trough across the inlet end of the basin is similar to the one at the outlet end of Basin No. 1, having perforations in the front and the bottom. The efficiency of this type of inlet should be studied under actual plant operating conditions.

Sedimentation Basin No. 2 is divided into two basins by a wall extending longitudinally through the center, each basin being approximately 24 ft. × 80 ft. in plan and 20 ft. deep, and each having a capacity of approximately 287,000 gal. Based on this capacity the retention period is approximately 3.4 and 3.8 hours at average and maximum rates of flow respectively. These are satisfactory periods of retention. These basins differ from Basin No. 1 in that they have intermediate baffles of the over and under type spaced at one-fourth points throughout the basin.

The openings underneath the baffles have an area of 36 sq.ft. The velocities of flow in each basin through these openings will be approximately 4.56 and 5.16 rpm. at average and maximum rates of flow respectively.

The efficiency of intermediate baffles is subject to considerable dispute. I doubt that they are satisfactory on small basins. These baffles might be of some value during periods when temperature differences throughout the body of water cause extreme short circuiting. The use of movable or completely removable baffles in the future promises to permit flexibility of operation.

The water leaves the basins over trough weirs having a 12-in. outlet at the end of the weirs next to the longitudinal wall. During the present rates of operation the water level is the same elevation on both sides of the weir, thereby defeating the purpose of the weir. The water being removed from the weir trough at one point will tend to cause short circuiting in the direction of the outlet so long as the weir does not have a free overflow. Further, the size of the outlet openings is not sufficient, thereby causing high velocities of flow and influencing the flow of

water to move in the direction of the openings.

The flow conditions throughout this plant indicate many fluctuations in velocities of flow, unequal distributions of water, turbulence-producing features and other disturbing influences. The conditions are particularly unsatisfactory between Basin Nos. 1 and 2, this being confirmed by analytical data, as well as by observations of actual plant operations.

The operation of many water plants is affected by physical conditions similar to some of the features discussed here, especially in the smaller plants. Frequently simple changes or additions will result in increased efficiencies. The water plant operator should not accept the design of his plant as being final, if results are not satisfactory. This does not mean that he should make needless or dangerous revisions in the design. It does mean that common sense observations as well as a little ingenuity may lead to solving some of the problems.

The water plant operator may learn what improvements are necessary in his plant, particularly in the sedimentation basin, by noting some of the following conditions:

1. The existence of high velocities.
2. The existence of turbulence.
3. The unequal distribution of flow.
4. The depth of sludge throughout the basin, noted when being cleaned.
5. The unequal distribution of suspended material.
6. The effect of temperature.
7. The elevation of water throughout the basin, particularly where weirs are installed.
8. The effect of intermittent operation of the basin.

Many sedimentation basins require changes in design after installation, perhaps only minor in nature. The engineering design is complicated by many factors and it is difficult to foresee all the conditions that may develop.

The purpose of this discussion has been to stimulate an interest in these routine problems that will result in a better understanding of the physical design features and operation of a sedimentation basin.

Keeping Filters Clean

By Walter A. Peirce and James W. Myers Jr.

Presented on Oct. 30, 1945, at the Illinois Section Meeting, Chicago, Ill.

RACINE, WISCONSIN—*Walter A. Peirce*

Mgr., Racine Water Dept., Racine, Wis.

THE foregoing title implies that filters are already clean and that the problem is to keep them clean. This discussion will necessarily be limited to experiences at Racine with rapid filters which have cast-iron collecting laterals and which use sand as the filter medium.

Construction Cleanliness

The procedure for making filters ready for initial operation demands that, upon completion of construction, the filter boxes be swept clean of all construction debris and washed down with hose streams. All openings in the collection system must be clean of obstructions, since a few plugged holes can easily disturb the uniformity of backwashing to an extent that will cause blind spots and mud balls. If gravel is used to support the filter medium it should be a washed material that has been inspected while being unloaded. A subsequent inspection, while it is being placed in the units, will insure the removal of sticks, coal, cinders and other debris from handling and shipping. The same care should be exercised to keep all foreign matter out of the filter sand.

Preliminary Washing

When the proper gravel and sand layers have been placed, all fine particles, silt and other light materials must be removed by backwashing. This will also insure the proper grading of the medium and level the surface. Best results will be obtained if the washing is done intermittently rather than continuously for a prolonged time. The rest periods will permit the adhering clay or silt to become soft, thereby making it easier to wash from the particle surfaces with a minimum amount of wash water. This initial washing should be continued until the effluent has no noticeable turbidity, at least not over 0.2 ppm. It is also desirable, after washing, to sample the top ½ in. of sand and check the screen analysis against the specifications.

Sterilization

The sterilization of the filter box, collecting system and filter medium is best accomplished by the use of a solution of highly concentrated hypochlorite, such as HTH or Perchloron. After the volume of water contained in the filter has been computed, the amount of chemical necessary to give a residual chlorine content of not less than 50 ppm. can be determined. With the filter full of water, hypochlorite solution should be poured into the supernatant liquid and well distributed throughout. Then the rewash valves

should be opened and the chlorinated water drawn down into the unit. By sampling the effluent from the rewash outlet it can be determined just when the solution has filled the filter box. If there is not sufficient freeboard above the sand it may be necessary to add water and hypochlorite so that the volume will fill the entire sand and gravel unit and leave an inch or two of water above the sand surface. The unit should then be allowed to stand for 48 hours. It should then be backwashed until residual chlorine as sampled from the top of the unit does not show more than the normal amount in the wash water being used. Another 48 hours should elapse before starting the filter and sampling the water from the rewash for bacteriological examination. After the above treatment such a sample should be "safe"—if it is not, the sterilizing process must be repeated.

Keeping the Filter Clean

Filters must be kept clean to insure a safe water supply and to prevent the formation of mud balls and caking. Any of these factors will prevent efficient washing and may even cause the lower strata of the units to be disturbed by the washing process. There are several methods in use which help obtain the final result, among which are pre-chlorination and surface wash. Experience at Racine has indicated that there is less tendency for mud balls to form if pre-chlorination is practiced, but this alone is not sufficient.

Washing Criteria

The filters are washed at a loss of head of 7½ to 8 ft. Runs from a few hours to over 300 hours have been obtained. Some operators feel that there should be a maximum time limit set for filter runs, but thus far we have not done sufficient research to justify setting an arbitrary time limit.

The backwash rate at Racine is 16 gpm. per sq.ft., which gives a sand rise of approximately 50 per cent. The sand rise is not checked further than to be sure that there is no loss of sand. Wash water lines have orifice plates installed to limit the flow to a safe figure. Orifice sizes were computed and have been found to be proper.

Removal of Mud Balls

For a number of years we were very complacent about mud balls—others probably had them, but surely not Racine! However, visual inspection showed some irregularity in washing and an investigation proved that Racine, too, had mud balls, although not of the magnificent size of those reported many years ago by John R. Baylis.

A search for a means of eliminating them was initiated. Study of the literature gave more information on the size and nature of mud balls and the interference which they occasioned in washing than on the methods of their elimination. After several unsuccessful attempts to eliminate them, the chief operator built a device which resembled a wide snow shovel, using galvanized wire screen mesh instead of solid plate for the blade. It had a binding of light metal to protect the edges and stiffening ribs in back of the mesh.

After starting the wash the operator would hose down the surface. He would then go out on the wash water troughs and use this screen shovel to pick up some of the sand, shake it to allow the sand to fall back into the filter and then dump the mud balls into the wash water gullet. The filter was allowed to wash thoroughly, dur-

ing which time the operator would fairly well cover the unit with his shovel. Because it extended the washing time and thus consumed more water than usual, this method was not the real answer to the operator's prayers. The one advantage was the low cost of the device.

Surface Wash

About 1932, there was installed a surface wash system consisting of horizontal pipes suspended about 2 in. above the surface of the sand when the filters were in operation. This arrangement was similar to the one in use at Kenosha, Wis., which had formerly been used as an air wash system. The drop pipe surface wash system devised by Baylis at the Chicago Experimental Filtration Plant was considered and it was decided to install something along those lines. However, a considerable amount of used piping was available and it was decided to use the horizontal pipe system because fewer fittings were required.

The pipes were supplied with water at regular city pressure (about 75 to 80 psi.). They were spaced about 20 in. center-to-center, with $\frac{1}{8}$-in. holes drilled at 5-in. intervals on both sides of the pipe to throw a horizontal stream. After the regular wash water had raised the sand, the surface wash was turned on and allowed to run until the washing was complete. The results obtained, so far as mud ball formation was concerned, were very satisfactory, as there was no further accumulation of mud. (Previous to using the surface wash the units had been rebuilt and cleaned, as will be described later.)

Within a year after starting operation it was found that the $\frac{1}{8}$-in. holes were increasing in size at an alarming rate. Not only did the unit require more water, but the jet velocity was lowered to such an extent that the full scouring effect was not being obtained. At first it was thought that the jetting of the sand was sandblasting the metal away much as the seats of leaking valves become wire cut, because of course the jets operated in a mixture of sand and water.

Records showed that the total elapsed time of washing a filter was 24 hours a year. We made up an iron pipe drilled with $\frac{1}{8}$-in. holes and another with a brass cap having similar holes. These pieces were suspended in a barrel partly filled with sand to such a height that the holes were below the top of the sand. Water at 80 psi. was run for 48 hours, the equivalent of two years' use in washing. Examination showed a little evidence of wear near one or two holes, but in most cases the burr from the drilling was still present. Both metals reacted in the same way.

This test indicated that a small amount of corrosion takes place while the filter is in operation. This corrosion is scoured off when the surface wash operates, resulting in a bright surface which corrodes again before the next washing period. In that way the metal is worn away and the holes enlarged, some of them to over $\frac{1}{4}$ in., and there is extensive pitting over an area near the openings. It was therefore evident that the immediate vicinity of the openings must be of non-corrosive metal. Consideration was given to brazing the holes shut and redrilling them through the brass, and also to tapping the holes and inserting brass nozzles, but both methods would have been rather costly in view of the fact that there were about 12,000 holes in the surface wash of the 12-mgd. plant.

It was therefore decided to rebuild the entire installation, resting the supply pipes 25 in. apart on top of the washwater troughs. Tees, from which vertical 1-in. pipes extend downward, were spaced at 28-in. intervals. These pipes have standard brass caps in which are drilled six $\frac{3}{32}$-in. holes 45 deg. from the vertical axis so that the jets are directed downward into the moving sand. This installation has 672 jets per unit instead of about 1,500, but the results are better than those obtained using the old system. This is probably due in part to the direction of the jet and in part to the increased velocity, since the same 4-in. supply line is used. After about five years of service the holes show some wear but very few are large enough to impede the operation. The same type of installation has been made in four 2-mgd. filters installed in 1936.

Rebuilding Filters

The original installation at Racine, in February 1927, consisted of eight units of 1.5-mgd. capacity. By the time the Civil Works Administration program was started experience had shown that the excess washing rates had caused upheavals of the gravel and mud balls had already been found. It was therefore decided to set up a project for removing, screening and replacing the sand and gravel so that the filters would be practically new.

All sand and gravel from one unit and the sand from another was removed and stored in the basement of the building and a platform was built across one end of the unit. On this platform a vibrating screen was set up and the gravel run over it. The gravel was then placed in the first unit in carefully graded layers. The sand was replaced, the filter washed and sterilized and put into service.

Since that time the operators have been especially careful not to wash at too high a rate. The orifices have been placed in the wash water lines and the surface wash installed. The results have been well worth the cost, as there has been very little upheaval of the gravel and no mud balls.

Metal Protection

The wash water troughs at Racine are cast iron and the surface wash piping is genuine wrought iron. The latter, as well as the fittings, requires some surface coating to prevent corrosion and this has been found to be quite a problem.

The Department has always felt quite strongly that a light-colored paint was very desirable as it enables the operator to observe the progress of washing if he can see some light-colored object through the water. In some plants submerged lights are used, but their maintenance presents many difficulties. Accordingly aluminum or white paints have been used at Racine.

When it was first decided to use light-colored paint, manufacturers' agents were consulted and several brands of aluminum were tried. Each agent was given a tabulation of operation conditions, such as pH and temperature, and they were asked to make recommendations as to methods and material to be used. Seven companies supplied sufficient paint for one filter, together with complete specifications for application. In one instance the manufacturer's agent supervised the work. After periods of one year and of two years these various units were inspected and the most satisfactory paint was selected.

An amusing incident occurred at the time. A salesman called on the chief engineer to sell a paint which he claimed would answer almost any problem; in fact he claimed that it could be applied to wet surfaces and would be almost permanent protection under water. The engineer told him that Racine was just then looking for materials to test. The salesman was given the specifications of conditions to be met, but no sample was submitted, although it was agreed that the department would pay for the paint.

The paints were applied in one, two or three coats and were of various natures, such as asphalt, bakelite and oil vehicles. The piping has since been cleaned and repainted with white on different types of undercoat, but we still cannot say that we have the final solution.

Great care was used in applying the paint, but there are conditions existing in a filter room which do not permit a good job. Of course the greatest problem is the high humidity. The pipe was cleaned by a thorough scraping and the use of an air-driven steel brush. After each coat was applied (in fact during application in some cases) electric fans and heaters were used to expedite drying. Canvas covers were built to keep the heat in the units. An even longer period of time than was suggested was allowed to elapse between coats, as it was evident that the coating was not thoroughly set. The last painting, done about a year ago, was not done in the filter room. A considerable amount of the piping had corroded so badly that it needed replacement and the entire assemblies were removed to the service building for cleaning and painting. Problems still exist, however. Asbestos-cement laterals are now being considered on an experimental basis as the material is light enough in color to use without painting.

We feel that there is probably some merit in the use of infra-red drying and are studying methods of installation for that type of work. Another promising solution is chemical treatment with some of the newer cleaning agents and surface protection by the use of phosphates. At least one eastern plant uses wash water troughs with vulcanized white rubber coating.

KENOSHA, WISCONSIN—*James W. Myers Jr.*

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Keeping filters clean is not only an operating problem but is also one of design. No matter how clever or resourceful an operator may be he can never overcome an inherent limitation in the design.

In most instances the plant is designed by one individual and turned over to another to operate. Occasionally, when subsequent additions are made to the plant, the operator does have an opportunity to be heard, but all too often such additions, except for a few modifications, must of economic necessity be patterned after the original design.

After the installation has been made the operator is compelled to do the best job he can with the facilities placed at his disposal.

Since this was the case at Kenosha, the best that can be done is to struggle

to keep filters clean. Kenosha's experience is not unlike that of hundreds of other plants and is typical of the normal evolution in filter plant design and operation. The first years of operation at this plant were a veritable nightmare for the operating staff, and much hard work and long hours are recalled.

Original Filter Installation

Perhaps a clearer picture of the efforts to keep the filters clean at Kenosha can be had by a description of the construction of the original eight 1-mgd. filters which were placed in operation in 1917.

These filters are rectangular concrete boxes providing sand areas of 348 sq.ft. each. The filter strainer system for each filter consisted of a central header with lateral branches and perforated brass strainers. This whole assembly was imbedded in concrete so as to leave only the upper portion of the headers and perforated tops of the strainers exposed. There were four strainers per square foot of sand area. Each strainer was punched with 33 $\frac{1}{16}$-in. holes so arranged that the wash water and air would be discharged in a horizontal direction as well as vertically upward. This was an attempt to cleanse the lower layer of gravel between the strainers. Each filter was equipped with four collecting gutters with semi-circular bottoms tapering from end to end. The lips of the gutters were only 12 in. above the surface of the sand. The gravel layer consisted of 9 in. of graded gravel ranging in size from $\frac{7}{8}$ to $\frac{1}{8}$ in. The sand was 27 in. deep. The specifications called for a sand having an effective size of not less than 0.40 mm. or more than 0.55 mm. and a uniformity coefficient of not less than 1.3 or more than 1.6.

Early Difficulties

This plant was designed by the New York Continental Jewell Filtration Company, Engineers, and without doubt was designed in accordance with the best standards of good practice for that day. In the light of today's accumulated knowledge and present-day standard of good practice, however, it lacked many of the essentials necessary to trouble-free operation.

Pre-supposing effective pre-treatment, the most important factor in the maintenance of filters is adequate washing. It seems almost ridiculous to repeat this truism but the fact remains that unless the sand grains are freed from silt and deposited material at *every* washing, there is bound to be an accumulation of this material and cracked and clogged areas will result.

The backwash in the original plant was limited to approximately $8\frac{1}{2}$ gpm. per sq.ft., or $13\frac{1}{2}$ in. vertical rise per minute. Although the agitation of the sand grains was augmented by compressed air the filtering media could never be thoroughly cleaned. Even during the winter months, when the cold, viscous water more effectively agitated and scrubbed the sand grains, the filters could not be washed clean.

Because of this ineffective wash, mud balls, clogged areas and cracks began to form. With the occurrence of the cracks, the backwash water coming up through the gravel followed the path of least resistance, which was horizontally across the surface of the gravel to the fissure or cracked spot. The velocity of flow was sufficient to displace this light $\frac{1}{8}$-in. gravel and form mounds. Before long the sand penetrated the thin spots in the gravel bed and plugged the strainers.

The only remedy for this was to remove all of the sand and gravel, clean out the plugged strainers, wash, rescreen and replace the gravel and sand. From 1917 to 1928 each filter had to be completely rebuilt three times.

Between these rebuilding jobs, every winter was spent washing and screening the sand in each filter to remove the mud balls. During the summer months the mud balls were removed by dipping into the expanded sand with a wire basket which was attached to a long handle.

Attempts were also made to remove alum floc and organic material from the sand grains by the use of caustic soda. The unit was first washed as thoroughly as possible; then drained down so that the water level was 12 in. above the sand. Approximately 2 lb. of caustic soda per sq.ft. of sand area was dissolved in this 12 in. of water.

After thorough mixing, by means of a propeller wheel which was mounted on a long shaft and rotated by means of an electric hand drill, the filter-to-waste valve was opened and the solution drawn into the sand until the level of the water was about 1 in. above the sand surface. After standing about twelve hours the filter was thoroughly washed. This treatment had some beneficial effect but nothing could ever overcome the inherent limitations in the design.

Subsequent Additions

By 1928 the consumption had increased to such an extent that four 1½-mgd. filters had to be added.

These new filters were rectangular concrete boxes having a perforated pipe distributing and wash system. The perforations were ⅜ in. in diameter and were located on the underside of the pipe. The spacing of these perforations was on 6-in. centers both ways. This grid was located 3 in. above the filter bottom. The 30-in. sand bed was supported on 21 in. of graded gravel ranging in size from 2½ in. to ⅛ in. The sand had an effective size of not less than 0.36 mm. and not more than 0.45 mm. and a uniformity coefficient of not more than 1.6 and not less than 1.3. The wash water troughs had sufficient capacity to carry a minimum wash rate of 15 gpm. per sq.ft. of filter area. The lips of the troughs were placed 24 in. above the sand surface.

Of considerable help in the pre-treatment of the water was the addition of a two-stage mixing basin and a coagulation basin which doubled the existing capacity and doubled the settling time. Under average load conditions the settling time was increased to six hours and 40 minutes, and under peak load conditions was increased to about two hours.

At the time these additions were made, the original filters were also equipped with large-capacity wash water troughs to permit the high-velocity wash of 15 gpm. per sq.ft. of filter area.

As stated before, experience at Kenosha reflects the evolution in plant design, and although these additions meet the existing standards of good practice, in our opinion they still fall short of providing an adequate wash at all seasons of the year.

Limitations in Washing the New Filters

During the winter months when the water was cold, the 24-in. vertical rise gave a sand expansion of 40 to 50 per cent and provided a very satisfactory wash. But during the summer months when the load on the filter was greatest

and the water temperatures were highest it was evident that double the backwash rate was required to secure a 40 to 50 per cent expansion of the sand.

The inability to increase the backwash rate sufficiently to get the expansion which was necessary to scrub and clean the sand grains effectively during the summer months resulted in a continuance of the mud ball problem. While it is true that these mud balls formed at a much slower rate, they were still very much in evidence and had to be contended with.

The mud ball problem was partially solved by the use of a simple homemade water jet consisting of a perforated cap fitted to a short length of pipe, which in turn was attached to a high-pressure hose line capable of delivering 70- to 80-lb. pressure at the nozzle. By working this pipe up and down through the hard areas during the backwashing operation the hard spots and mud balls were effectively broken up with these high-velocity jets. This was the forerunner to the surface wash system.

Surface Wash

While the recorded history of the surface wash experiments go back as far as 1907, to the author's knowledge there was no widespread plant scale use of this system in this section of the country until its proven success at Kenosha in 1933.

Kenosha's surface wash system is a perforated pipe grid placed 3 in. above the unexpanded sand. The lateral pipes are arranged so that there is one lateral directly beneath each wash water trough and one lateral 12 in. from each side wall with two laterals between each trough. This gives a variable spacing of 12 and 21 in. Each lateral is drilled with two sets of diametrically opposite holes at 9-in. centers so as to throw a horizontal stream both ways. The holes in adjacent laterals are staggered so that the high-velocity jets interlace. The old cast-iron supply line to the old air grid is utilized as the surface wash supply, carrying a pressure of 80 psi.

Since the labor of installation was performed by the regular operating staff, the total capital investment in the system was mainly that of piping and valves. Since the cost was small no attempt was made to secure the most economical spacing of the laterals as we were mainly interested in results.

In the operation of the surface wash system the sand is expanded through this horizontal sheet of high-velocity jets. The rate of wash is approximately 6 gpm. per sq.ft. of sand area. The high-velocity jets create a turbulent scrubbing action which effectively eliminates all mud balls and hard spots.

On some earlier spot checks it was found that the combined backwash and surface wash required about 0.7 per cent more wash water than the conventional backwash alone. Had it been possible to increase the backwash rate sufficiently to accomplish a comparable cleansing job, the amount of water used would undoubtedly have been substantially more.

The difficulty Peirce reported with the enlarged hole size in the lateral system was also experienced at Kenosha. We too were of the opinion that corrosion was the cause of the enlarged holes, but are now convinced that it is due to the sandblasting that takes place around the hole as a result of the low pressure area created as the high-velocity jets leave the pipe. We actually went to the trouble of soldering

the holes shut and redrilling the holes through the solder. It was thought that corrosion could be stopped if the exposed steel was coated at the points where the galvanizing had been broken. Although the solder did place a protective coating over the exposed steel, the hole enlargement still persisted, so we have concluded that it is sandblasting that causes the erosion around the holes.

Perhaps the Baylis system, which uses perforated caps, is the answer, as these can be replaced at a nominal cost.

The surface wash system, without question, is the answer to keeping filters clean at Kenosha. We recommend no particular style or type of surface wash system, and, since they all accomplish the same result, the selection of the proper type is merely a case of economic choice.

Erratum

In the Committee Report, "Summary of 1945 Pension and Retirement Legislation" (Jour. A.W.W.A., **37**: 1119 (1945)), Arkansas was reported as having adopted "no pension legislation in 1945." That was in error. Act 132, passed by the Legislature of Arkansas, February 27, 1945, authorized any city of the first class, owning and operating water works distribution systems "by or through a Board of Water Commissioners, to provide a plan for Social Security, Old Age Pension and/or Retirement Pay for part or all employees of said water works system under such plan as such Board of Water Commissioners may provide."

Rehabilitation of Sandstone Wells

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THE multiple problems involving the rehabilitation of sandstone wells in northern Illinois should be approached in the same manner as any other engineering project. Accurate, factual data should be obtained on the existing condition of the well, as well as on the past performance, before attempting to estimate the possible future benefits of repair and the methods of obtaining these benefits. Because it is not economically possible actually to view these wells as one would a building, our own imagination shrouds the problem in mystery. The unseen provokes the unknown. However, there are many methods of inferring indisputable facts concerning the unseen and the supposedly unknown.

The location of a well is of prime importance to the existing and future scheme of any water supply system. It is sometimes desirable to recapitulate and reconsider in order to determine the advantages or disadvantages of the present location of a well. Since the cost of rehabilitation may be quite high it has on some occasions been found more economical to drill a new well. On other occasions it has been found desirable to obtain better quality water. In some cases it may be wise to reserve the existing well for standby service. Serious consideration should be given to the local rate of water level recession and the possible future life of the well supply even with the best of repair and maintenance.

Such considerations as the area to be served (residential, manufacturing or commercial), the trend of the water demand, the present and future size of distribution systems, the present or future type of treatment, the question of obtaining surface water, the desirability of a concentrated or of a segregated well field—all of these are *first* to be considered.

The constantly increasing demand for ground water in this Chicago area has resulted in an irregular but unquestioned recession in water levels over the general area since 1890. Since the rate of recession is not always constant and is often too slow to be noted over a short period of time, it is necessary to consult long-time records available for the general area. Every effort should be made to check the available records for accuracy, since very often false and misleading data may be obtained from an air line of unknown length or from a well in which a false head is maintained above the pump bowls. These records must be interpreted with due respect to the past, the present and the expected future demand for water in the surrounding as well as in the immediate vicinity.

Size of Well

Assuming the well under consideration to be in the desired location, the diameter of the existing bore is next to be considered. Many wells penetrating the deep sandstones were drilled

many years ago and the diameters throughout their entire depth are now too small when considered in terms of present-day desired capacities. Observations indicate that many of these old wells, while penetrating the sandstone formations, had a bore diameter ranging from 8 to 12 in. at the top, and finishing 4 to 5 in. at the bottom. These wells apparently produced sufficient water in their day. However, increased demand and recession of water levels have necessitated larger pumps and deeper settings of pumping equipment. Wells of larger bore are therefore required, not only in the area of deep pump setting, but are also desirable through the aquifers. However, the cost of increasing the diameter of the bore in an old well is often greater than the cost of an entirely new well. Thus, the picture is now revised. A well must be developed to meet certain capacity requirements and to provide for efficient pumping equipment. A discussion by A. O. Fabrin [W.W. & Sew., **91**: 371 (1944)] on the subject of well diameter and pump size provokes some thought.

Depth of Well

The history of deep wells in the area under discussion brings forth some interesting observations. The first few deep well contractors to operate in this area were oil field men from the East who were accustomed to drilling deep wells, and so the natural inclination, by virtue of heredity in this business, was to drill them of similar diameter and depth. Procedures in oil well drilling were such as to produce wells of relatively low capacity for a valuable product. In contrast, water well drilling serves the end of producing a low dollar value product at high capacities. The depths of these wells were often excessive insofar as quality and quantity and source of water were concerned. A few consequences resulting from drilling wells of excessive depth include high chloride content, high temperatures and a tendency for some of the formations to be of a thieving nature, thus creating excessive depths to water for both the static and the pumping heads.

In Chicago and the surrounding area, observations have led us to believe that wells drilled through the Galesville sandstone will generally produce the largest desirable quantity of usable water for many industrial purposes, although not always adaptable to human consumption.

Rehabilitation

Regarding the rehabilitation of a Galesville well, if the location is appropriate and if the diameter of the bore is of sufficient size, the problem will be that of increasing the production. During the life of most sandstone wells, all water-bearing formations have been open and the waters at one time may have moved through the well from one formation to another, and at a later period of time the reverse procedure may have taken place. The extent and time of this exchange of waters has depended (1) on the relative static heads of the aquifers, (2) on the dynamic heads prevalent during pumping, and (3) on the relative abilities of the various aquifers to give and take water. Other controlling factors include the pumpage in the immediate and surrounding area and the resultant recession of static heads of these various aquifers.

By virtue of some of these movements, chemical reactions have altered the producing characteristics of these aquifers. For example, limestone wa-

ter, having its iron oxidized by exposure to air and transferred to the higher producing sandstone formation of lower static head, would tend to reduce the sandstone porosity particularly at the surface of the sandstone, which acts as a filter for the water entering the formation.

In another example, suggested many years ago by Leverett in 1897 and Slichter in 1910, a deposit is formed on the well wall in the sandstone area. Slichter stated, "For some reason the water-bearing sandstone has become 'clogged' in the neighborhood of the wells so that the sandstone is not able to transmit as much water as formerly. This is a common experience with such wells, especially when operated under high drawdown. The writer believes that this clogging is due to the liberation of CO_2 by the reduction in pressure. It is not believed that it is due to mechanical clogging alone." This may be explained by considering that the sandstone water, as it enters the well bore during withdrawal at high rates, undergoes a very large drop in internal pressure. This results in a strong tendency to shift the natural chemical solubility equilibrium, resulting in a small but accumulating deposit of limestone on the surface of the sandstone on the wall of the well bore. This deposition reduces the porosity and the capacity to yield water. Such deposits are primarily on the surface and must be removed to increase the porosity and to permit a greater rate of entrance of the water.

The most common method of removing this deposit is by shooting the sandstone in the producing zone into the well with nitroglycerine, thereby crumbling the surface area. A predetermined indication of the most favorable shooting area in the sandstone is most helpful. This information can be obtained by a geophysical survey. Such a survey includes the electric logging of the well. By correlation with the original log, considerable valuable data may be obtained. There are many modifications of the electric logging work, and as many of these modifications as practical should be made in order to obtain a complete picture of the well in question. When the areas of most probable high permeability are located, shots of approximately 100 to 600 lb. may be exploded opposite these areas in the well bore. It may be necessary to use two or three such shots in order to obtain the best results, and an indication of these results can be judged, to some extent, by the amount of coarse sandstone bailed out of the well. No method, however, can replace the production test to indicate the final effectiveness of the rehabilitation.

It is not unusual to find that the original production capacity can be reclaimed. To substantiate this last statement, a well in the Elgin area was drilled in 1938 to a depth of 1,222 ft. This well penetrated the Galesville sandstone and was found on completion to have a 48-hour tested capacity of 1,250 gpm., with a 160-ft. drawdown from a 123-ft. static level (or a specific capacity of 7.8 gpm. per ft.). Six years later, in 1944, before rehabilitation, this well produced, on test, 540 gpm., with a 93-ft. drawdown from a 143-ft. static level (or a specific capacity of 5.8 gpm. per ft.). After rehabilitation following the above-mentioned procedure, the well was tested to produce 540 gpm., with a 65-ft. drawdown from the same 143-ft. static level (or a specific capacity of 8.3 gpm. per ft.). This represents an increase of 30 per cent for specific capacity.

Eleven cubic yards of sandstone was bailed out. It should be noted that the dynamic or pumping level did not reach the original pumping level for the same rate.

Other rehabilitation projects with more phenomenal success have been recorded but complete data before and after are not available for presentation here.

Rehabilitation of a well to increase its capacity does not refer to a rise in static level but rather to a rise in pumping level with the same or greater rate of withdrawal. Of course small changes in static level may be observed as the result of resting the well during rehabilitation. Rehabilitation increases the ability of an aquifer or, by a combination of circumstances, the ability of a well to produce more water per foot of drawdown. Rehabilitation may and has raised or lowered the static level of the water in some wells. In each case, this can be explained by the fact that the "giving" or the "taking" aquifer in the well has been affected to give or take more water respectively.

In a few fortunate cases of rehabilitation the ability of a sandstone to give water has been increased and, as a result, the crevices in other aquifers in the well have been more readily replenished during idle periods. During pumping periods, these crevices or storage reservoirs feed water into the well at a high rate for prolonged periods with less drawdown than that necessary to extract the water from the original sandstone source itself.

In addition, much has been said and much more can be said concerning the interference by pumping other wells in the area of immediate and prolonged influence. It is not the purpose of the author to discuss the hydraulics and mathematics involved in such studies. It is enough to say that it requires but little imagination to picture the effect of two people rather than one with straws in the same soda glass.

A word of caution regarding the shooting of a well: If liner casings are adjacent to the area to be shot, or a long string of casing is in the hole, then such casings must be removed before any heavy shooting is effected; otherwise, this casing will collapse and much added expense will be incurred.

Other methods of rehabilitation include under-reaming and acidizing. Under-reaming is not as effective as shooting and does not have the support of the drillers, nor the romance with which shooting is blessed. Acidizing is handicapped with the problem of applying the acid in high concentration at the desired point in the well without filling the whole well with acid. Nor does it increase the diameter of the hole. Only one record is available of a sandstone well in the Cook County area having been acidized. The data in this case are not sufficient to condemn or recommend the procedure.

Salt water, when found to be entering the well in objectionable quantities, can be reduced by plugging off the lower part of the well, if this has been found to be the source. Most of these operations have been successful, but several failures are on record. One of these failures has been attributed to excessive shooting in the lower part of the well, which prevented any possibility of obtaining a tight seal at the proper depth.

In many wells it is desirable to "cement in" the upper top casing in order to exclude surface water or poor quality water and hydrogen sulfide from the well. This procedure also has a distinct advantage in preventing any possible future corrosion from the outside

of the casing. The more successful applications involve the introduction of cement grout to the lower end of the casing and forcing it upward around the outside to fill the annular space to the surface.

The approach of the rehabilitation period is usually first noted by lower pumping levels and reduced capacity. Careful and regular water level readings, plus observations of flow meter charts, will usually give much advance notice of the impending failure. The air test line for determining water levels is, to the water works superintendent, what the patient's pulse is to the doctor, because it is an indication of a strong or a weakening condition. The flow meter yields data of distinct aid to the air line indications, and often a few watt meter readings may pin repair indications directly to pump trouble or to well trouble. On many occasions a chemical analysis of the water will assist in the determination of the water source or change in source. In some cases rehabilitation requires only a deeper pump setting to meet the receding water level in the vicinity.

Rehabilitation of Limestone Wells

There are areas outside of Chicago where sizeable quantities of water are being obtained from the first limestone. These areas lie south, southwest and west of the city. The quality of this limestone water is not always the best for the purpose for which it is used. However, chemical treatment can and has been successfully applied. This upper limestone water has the great desirable feature of being cold water (51–53°F.).

Water in limestone is present by virtue of creviced areas or reef areas (State Geological Survey Bulletin 65). The former are simply chains of breaks or cracks or fissures in the limestone. These fissures may be vertical weathered crevices or, as generally found in the lower part of the limestone, they may be horizontal crevices or solution channels in the formation. There is some evidence to show that both types of crevices are often fed locally or at some distant point by rainfall and infiltration. The reef areas are systems of honey-combed rock and the sources of stored water are the same as those for the creviced areas.

The rehabilitation of a limestone well is often successfully accomplished with the use of acid. Hydrochloric acid of a strength of 15 or 30 per cent, inhibited to prevent corrosion and with the addition of other ingredients to keep the dissolved iron salts in suspension, is introduced into the well under pressure. This acid has a tendency to dissolve the more soluble portion of the clays that have clogged the inter-joining creviced areas. Upon clearing these crevices, substantial increases in well capacities have been noted. Several failures of this treatment are on record and it should be proper to obtain experienced authentic advice on this type of rehabilitation.

There is also some question still concerning the proportion of the effect of some of the successful applications that should be attributed to the cleaning of the pump by the acid. Here again, a good production test, properly interpreted before treatment, will yield pertinent information.

Economics

The rehabilitation of a well seems to go hand in hand with the rehabilitation of the well pump. There is perhaps as much widespread cost to such operations as there ever has been. However, it is not unusual to find that

repairs to pump and to the casing and well will amount to $10,000 to $20,000. Oftentimes repairs to pump may involve a complete new unit either to replace poor operation efficiency, to eliminate corrosion or to fit the existing hole size at a lower setting.

Serious consideration should be given to replacing an inefficient pump with one of modern efficiency and of size and design to meet the demand requirements. This consideration should also go hand in hand with the question of "rehabilitation or new well." If corrosion is experienced there should be no hesitancy to ask for assistance. Answers are not always readily available but if they are apparent, there should be no excuse to ignore any opportunity to make use of them. If it appears necessary to substitute cast-iron bowls with bronze at a 100 per cent additional cost per bowl, the increased lifetime of the pump will well warrant the added investment. Unless operation and repair expenditures are made on a fly-by-night basis, there should also be no hesitancy to provide protective coating for column pipe when water of high mineral content is used.

The total cost of securing and maintaining a well supply should be considered along with any disadvantages of poor water quality and compared with the cost of water from other sources. This provides a common dollar-and-cents basis on which to proceed with an efficient program. The initial cost of installation or rehabilitation, when prorated on a basis of dollars per million gallons, is often a very small percentage of the cost of pumping and treatment per million gallons of delivered water.

Summary

No rehabilitation job should be started without preliminary planning in a sound engineering manner using basic indisputable facts. The facts are not always available but much can be learned: (1) by a thorough, well-performed and interpreted production test to learn of the present character of the well and pump; (2) by chemical analysis of the water to assist in interpreting the data; (3) by an assembly of the past history of the well and of the water levels with reference to past and expected recession, the water demands and the construction of the well; (4) by geophysical logging of the well to determine unknown factors such as casing and liners, size of hole, lost tools, bridging, past shooting and creviced areas; (5) by assembling the facts concerning future demand and quality and correlating with the facts concerning the future underground water resources of the area; and (6) after rehabilitation by a thorough production test to indicate the effectiveness of the rehabilitation and to be available for reference when the next rehabilitation job becomes necessary.

All wells should be equipped with an air line, a sampling tap on the discharge line, and in many cases a flow meter. In all wells, the pumping rate, pumpage, static levels, pumping levels and chemical analysis of the water should be checked at specified intervals.

DISCUSSION—*Carl Duy*

Engr., Water Works, Aurora, Ill.

The writer would like to discuss Mr. Millis' paper strictly from an operator's viewpoint.

The operators of all water systems deriving water from wells can make a worth-while contribution to their operating statement by taking their wells more seriously and giving more daily attention to their productive possibilities. It is the writer's belief that, if there is no information available on the wells, every effort should be made at the first opportunity to make such investigations and tests as are necessary to determine the depth, the diameter and the amount of casing installed in each well. Once this information is obtained the capacity, drawdown and power cost tests should be made a part of the permanent record and the tests should be conducted semi-monthly.

The tests for pumping levels should be conducted by means of air-line and air-pressure gages. These should be periodically checked with electrodes to prevent the occurrence of false readings on the operating levels and capacities. It is also essential to have complete data and factory tests on the pumps so that if deficiencies exist they can be properly located. The matter of time is an important consideration of these tests. They should be taken over a period of at least 5 to 8 hours. Shorter periods may yield erroneous capacity figures, as some wells will pump down and reduce their specific capacity after a greater period of operation.

It is also important to have a record of the recovery period, as well as regular temperature readings of the water. If temperature readings are available, any change taking place will quickly indicate water coming in from a new source or formation. In addition the water should be tested for any change in its chemical qualities at least as often as once a year. This information is useful to consumers in any installations that may be contemplated for domestic or industrial purposes.

At the present time Lake Michigan water should not be considered by municipalities as far from the lake as Elgin, Aurora and Joliet, as the cost of transmission of water would be very high. Due to capital charges the cost of water delivered would be much in excess of the present cost. Possibly some time in the future the density of population between the corporate limits of the city of Chicago and Aurora, Elgin and Joliet will create a demand for water which would warrant capital charges in keeping with a project of this nature.

There are many wells in the northern part of Illinois of a size that it would not be advisable to rehabilitate. Wells constructed during the last twenty years are in practically all cases much larger in diameter both at top and bottom than wells constructed at an earlier date.

There is considerable difference of opinion relative to the depth that a well should be drilled in the northern part of Illinois. Some are of the opinion that there is very little water below the Galesville member of the Dresbach system. Others believe that there is considerable water in the Mt. Simon sandstone, the lower member of the Dres-

bach system. Water obtained from the lower member is considerably higher in temperature and it is believed that this formation has a high yield.

Shooting the well is the most common means of increasing the specific capacity. As Millis stated, it is very important that the present casing installed in the well should be properly located before shooting so that there will be no danger of collapsing the casing. In shooting the well it is advisable to place several explosives at different levels throughout the water-bearing sandstones instead of using one or two heavy shots.

There are very few, if any, cases on record where acidizing has increased the productive capacity of a sandstone well, although there are many cases where a substantial increase in production capacity has been obtained by acidizing a Niagaran limestone or gravel wall well.

The making of a geophysical survey prior to rehabilitating a well has considerable merit, although the data obtained cannot be considered 100 per cent accurate.

At the completion of the rehabilitating of a well or wells, very lengthy tests should be conducted on the well. The adjacent ones should also be tested to see what effect the rehabilitated well had on the older ones, especially if a great amount of shooting was done in the rehabilitation. These data are very important for the operating records.

In any rehabilitating work contemplated, the following items should be given careful consideration before the project is let:

1. Age of the well.
2. The average life of casing in wells constructed in vicinity of well to be rehabilitated.
3. Original production capacity.
4. Present production capacity.
5. Previous shooting of well, if done.
6. Estimated cost of rehabilitation.
7. Estimated cost of new well.

DISCUSSION—*Edward Wilson*

Engr., Corn Products Refining Co., Argo, Ill.

Mr. Millis' statement, "The unseen provokes the unknown," is interesting, for the more experience I have with deep wells and underground water flow, the more I think of those lines by Robert Owen, "All things I thought I knew but now confess, the more I know I know, I know the less." Working with underground water is like playing golf; just about the time you think you are getting good, you go out and shoot the worst game of the season. The same is true of wells; about the time one thinks he knows something about them, the unexpected shows up and he wonders if he knows *anything* about them.

At the Argo Plant of the Corn Products Refining Company, in what is called the "old well system," there are eight wells drilled to a depth of about 1,800 ft., with diameters of 16 in. at the top and 8 in. at the bottom. These wells were pumped by means of a shaft and tunnel system 360 ft. under the ground. That is, the water in the well flowed by gravity through the underground pipe to an ordinary centrifugal

pump, in a pump room at the bottom of the shaft, which delivered the water to the surface.

In 1933, a rehabilitation program was started and after cleaning and shooting a number of the wells, there was an increase of about 15 ft. in the pumping water level, or a static level of around 308 ft., pumping 2 mgd.

There was then a rapid drop in water level and by 1940 it was down to 350 ft. for a flow of 2 mgd. By 1941 it was no longer possible to obtain a flow of 2 mgd.

The next rehabilitation plan called for some new wells with individual deep well pumps, for the old wells were too small in diameter to take deep well pumps.

The first of the four new wells, which was ready for operation in August 1942, was drilled to a depth of 1,540 ft. (just below the Galesville sandstone). It was 26 in. in diameter at the surface and 17 in. in diameter at the bottom, cased and concreted 500 ft. down from the surface. The tops of the pump bowls were set at 500 ft., and the pump designed to deliver 1,000 gpm.

Before starting this well the water stood at 340 ft. and after pumping 1,000 gpm. it dropped to 440 ft. The old well system flow dropped to 500,000 gpd., so a total of approximately 2 mgd. was obtained from the ground.

The starting of the second well in 1943 brought the end of the old well system—it was dry. There were also indications that the 500-ft. pump setting should be lowered. The pumping water level of the second well was as low as 469 ft., while the water level in the first well dropped 28 ft. for an increased total flow from the ground of 650,000 gpd.

Accordingly, the next two well pumps were set at 600 ft. and the first two well pumps were changed to 600 ft.

Table 1 shows the water levels at the time each well was first put into operation. (All measurements are from the ground surface.) As can be seen from the table, there was a drop of 74 ft. in the static water level from August 1942 to January 1945.

TABLE 1

Well No.	Date	Water Level Before Starting Pump—*ft.*	Water Level While Pumping 1,000 gpm.—*ft.*	Total Flow From Ground—*mgd.*
1	Aug. 1942	340	441	2.0
2	June 1943	350	463	2.4
3	June 1944	380	480	2.5
4	Jan. 1945	414	*	

* Test not run on this well.

Mr. Millis states: "The quality of the water should be considered." This is very true, and when quality is considered it may be better to use some source of supply other than deep wells. The chemical analysis of a deep well cannot be accurately determined until the well is complete and in operation. For example, an analysis of the water from the first three wells at the Argo Plant checked very closely but the fourth well showed a wide variation, even though all the wells were located on an area of approximately 75 acres. The analyses are shown in Table 2.

TABLE 2

	First Three Wells ppm.	*Fourth Well ppm.*
Total Hardness	308	718
Calcium Hardness	205	428
Magnesium Hardness	103	291
Sulfate	222	906
Chlorides	154	239
Total Dissolved Solids	684	1,539
Temperature	60°	56°

The No. 4 well presented a new problem and it was decided to rehabilitate it so the water could be used. It was analyzed somewhat as follows:

1. The higher chloride content led to the belief that the water was coming from the lower strata or from Mt. Simon sandstone.

2. The high dissolved solids content and the lower temperature indicated that the water was coming from the upper or limestone strata.

3. One of the old wells, located 30 ft. away from Well No. 4, went down to a depth of 1,866 ft. and was not cased in the upper strata. Was the water from this well getting into Well No. 4? To check this, salt was added to the old well while Well No. 4 was running and in less than five minutes there was a definite increase in the chloride content in the water from the new well.

It is planned to fill up the old well to the bottom of the new well and put a concrete plug in the old well approximately 500 ft. below the ground surface, thereby keeping the undesired water from getting into Well No. 4.

All of the wells are equipped with air lines, discharge pressure gages, recording flow meters and indicating ampere meters on the motors. These are read daily when a well is in operation. This equipment not only tells the story of what each well is doing, but it also indicates the pump performance. The ampere meter plays an important part in deep well pump operations. One day, as the discharge valves on one of the well pumps was being throttled, the ampere pen started swinging, instead of going lower, as it usually does when the load decreases. This indicated that the shaft had stretched, causing the pump impellers to rub on the pump bowls. The impellers and shaft were raised by means of the lateral adjusting screws, and the ampere meter immediately came back to its normal position. Later, when this pump was pulled, score marks showed where the impellers had been rubbing. If this rubbing had continued, the pump would have been ruined in a very short time.

Present Condition of the Ohio River

By Arthur R. Todd

Supt. of Filtration & Chemist, Wheeling Water Dept., Wheeling, W.Va.

Presented on Nov. 16, 1945, at the West Virginia Section Meeting, Wheeling, W.Va.

WE now have arrived at the crossroads where we must ask ourselves the question: "Has the Ohio River water become so polluted that it is no longer fit to be used as a source of public water supply?" We at Wheeling have been seriously considering this question for some time but until now we have had a kind of child's faith that something or other would happen to halt the ever increasing pollution of the river. Just what that something would be was not quite clear —perhaps a state or federal law, or a reformation on the part of industries and cities. However, the miracle did not happen and we are face-to-face with the fact that every year since 1826 the Ohio River water has been changing for the worse. For the first 92 years —from 1826 to 1918—Ohio River water was used at Wheeling as pumped— no filtration and no sterilization—although typhoid became very widespread from 1900 on. In the year 1913 there was a big fish kill—so many fish were floating on the river that crowds gathered on the banks to watch the spectacle in awe; old timers still talk about it. Very few fish have been able to live in the river since that time.

Chlorination was started in 1918 and immediately the typhoid death rate declined. The present filtration and purification plant was put into service in 1925 and the typhoid fever almost entirely disappeared from Wheeling. The few cases that have occurred in the city since then were contracted elsewhere.

From 1925 to 1933 the purification process consisted of treatment with alum, lime and chlorine. To produce a chlorine residual of 0.1 ppm. a feed of 1.4 lb. per mil.gal. was required in 1918, $2\frac{1}{2}$ lb. in 1925, 4 lb. in 1933, 8 lb. in 1939 and 14 lb. in 1944. Thus in 26 years the amount of chlorine necessary to produce a 0.1-ppm. residual has risen from 1.4 to 14 lb., or ten times.

The first big taste and odor problem occurred in 1928, and the same problem has recurred periodically. In 1934 the purification chemicals were changed. Ferrous sulfate was substituted for alum, as it was found that the river had sufficient iron salts to require a coagulant only about 10 per cent of the time. Ammonia and pre- and post-chlorination were used with fairly good results for a few years. Carbon was given a thorough try and was included as a regular purification ingredient.

However, when the taste and odor problem would be apparently checked, within a year or two the river would get worse and the trouble would start all over again.

In 1940 we experimented with "break-point" chlorination. A $3,500 chlorinator was purchased and the process was adopted in 1941. In that year, 57 lb. of chlorine per mil.gal. of water were required. For the next

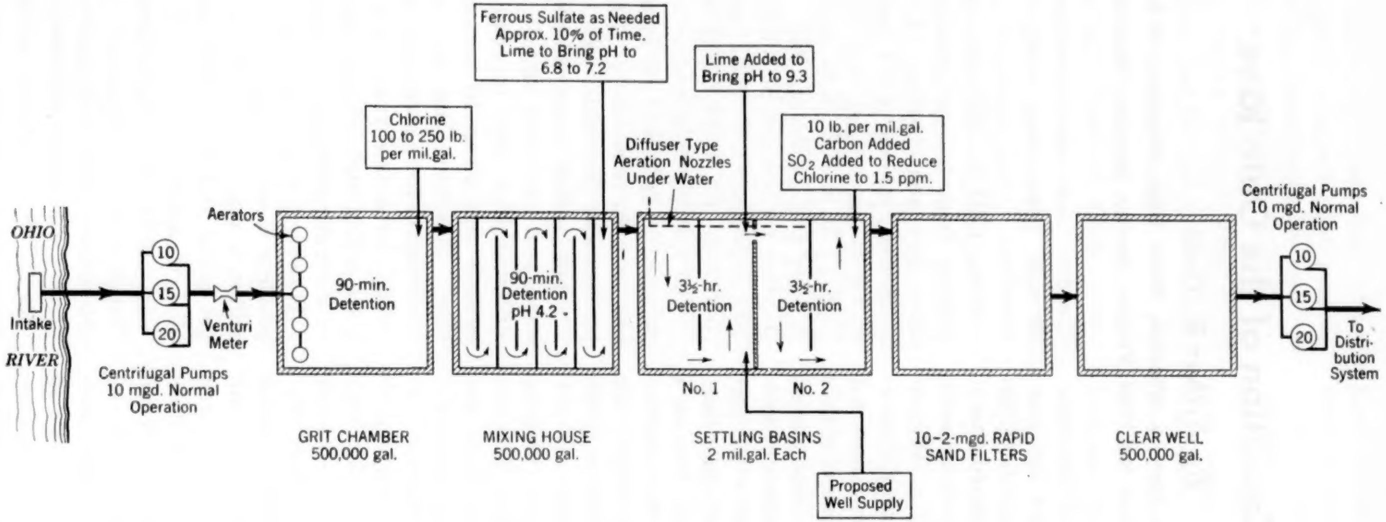

FIG. 1. Flow Diagram of Wheeling Water Works, Wheeling, W.Va.

Average Raw Water Analysis

Total Alkalinity, *ppm.*	3.0
Carbon Dioxide, *ppm.*	5.0
pH	5.4

Tap Water Analysis

Total Alkalinity, *ppm.*	22.0
Phenolphthalein Alkalinity, *ppm.*	3.0
Residual Chlorine, *ppm.*	1.5
pH	9.3

one and one-half years everything was "hunky-dory" and we threw out our chests, contemplating how smart we were. Then came the war. Plants began to operate on three shifts with additional help on each shift, resulting in three times the pollution. Also there were new industries galore. In the all-out war effort very little attention was paid to wastes. The final blow was the start of operation of the butadiene plant at Karbuta, Pa. To meet this situation the purification process had to be changed again. Another $3,500 chlorinator was purchased and installed for super-chlorination. Sulfur dioxide equipment and an 800-cfm. Roots-Connersville air blower were purchased and installed. In addition, a standing order for carbon was placed and the split lime treatment was introduced. The present process consists first of chlorine. The peak summer requirement is 185 lb. per mil.gal. and the winter high is 250 lb. per mil.gal., with a retention period of 90 minutes and a pH of 4.2. The pH is then increased to 7.0 and the retention period increased to three and one-half hours, followed by another increase in pH to 7.5 with another retention period of three hours. The water is then de-chlorinated to below 2 ppm. with sulfur dioxide, and carbon is added to stabilize the effluent.

The results of this process are palatable water during May, June, July, August and September; a passable water in February, March, April and October; and a poor water in November, December and January. November is the most troublesome month.

Dropping the pH from 9.3 to 7.5 has greatly increased red water troubles, but when there is a choice between taste and odor complaints and red water complaints, the latter are preferred.

Practical plant scale experiments have demonstrated the fact that by using soda ash instead of lime a better tasting water can be produced at any pH above 7.5. Wheeling has hesitated to use soda ash because of the added expense. The tabulation below shows the increase in chemical costs.

Cost per mil.gal.	*Fiscal Year*
$2.53	1938–1939
2.78	1939–1940
2.92	1940–1941
2.87	1941–1942
3.21	1942–1943
6.58	1943–1944
5.76	1944–1945

Due to the increased pollution of the river water, the rise in cost for chemicals in the past five years is $40 per day to purify the same amount of water.

Prior to the start of operation of the Karbuta plant, the filter runs averaged 63 hours; now the average is 30 hours. Except in the spring, when the water was warm and the solubility of the air in the water was decreasing due to the rise in the temperature of the water, air binding of the filters was unheard of. This week the average filter run might be 53 hours, with no air binding. Next week, due to escaping gases from the water, the filter runs may drop to eighteen hours because of air binding. The installation of air release valves on the filter influent line has relieved this situation somewhat. In order to prevent future air binding as the filters are rebuilt, it is planned to install an air release vent in the false bottom of the filters.

The answer to the question "Has the Ohio River become so polluted that

it is no longer fit to be used as a source of public water supply?" is "YES." It is true that the Ohio River can be sterilized and it is also true that sewage can be sterilized; but who would want to eat or drink sterilized sewage? The Ohio River is now nothing more than an open drainage ditch. More than a million people empty their waste products into it daily and a few miles downstream other people drink it. No greater fallacy has been fostered on the American public then the old adage "a stream purifies itself in flowing a few miles." We have finally become realists. No longer do we look for a miracle of a clean, healthy Ohio River, full of fish life, boating and boys and girls swimming.

Since the Ohio River is not water, but diluted sewage loaded with organic and industrial wastes, it becomes evident that the liquid must be treated as such. Mere sterilization by passing it between silver plates is not sufficient; the organic load must be removed. This can be accomplished in three ways. The first is super-chlorination, which is the present process at Wheeling. The second process, now being tried at Weirton, W.Va., is the use of chlorine dioxide. A third would be the installation of a modern sewage plant with primary and secondary treatment of the biological type, whereby the diluted sewage coming down the Ohio River could be processed by first passing it through the sewage plant to remove the organic matter and then through the water treatment plant for further refinement.

The Wheeling Water Department is convinced by experience that there is a limit to the load an ordinary rapid sand filtration plant can carry and believes that any additional pollution of the Ohio River will result in a failure to produce a water satisfactory from the standpoint of palatability. In order to meet this ever increasing rate of pollution, it is planned to mix well water with the river water. The plans call for 10 per cent well water this year, based on the increased rate of pollution of the Ohio River each year for the past five years. By 1947, 20 per cent ground water will be required and by 1949, 30 per cent. The cost of a well equipped to supply 10 per cent ground water will be about $10,000. However, the chemical cost should be reduced by 1 per cent for each 1 per cent of ground water added up to 30 per cent of ground water. Should we use more than 30 per cent ground water, the resulting increased hardness would be objectional and softening would be required.

Main Cleaning

By Whitworth Cotten

City Engr., Petersburg, Va.

Presented on Nov. 9, 1945, at the Virginia Section Meeting, Roanoke, Va.

DUE to the increase in population of Petersburg, resulting from the expansion of nearby Camp Lee, the maximum daily consumption of water has increased about 50 per cent. On days of heavy consumption, severe drops in pressure were observed in a large portion of the distribution system. A check on available fire flows indicated a loss since the last check made by the Underwriters about twenty years ago. Realizing the inadequacy of the system, it was decided to employ a consultant to make a complete study of the city's distribution system, and to make full recommendations as to the present and future needs in order that the city would be provided with a sound program of water works improvements for postwar projects. The Pitometer Company was employed to make this survey and report, and the work was completed in March 1945. The report recommended a $316,000 improvement program designed to meet the estimated requirements until 1960.

Part of the work done in this survey was the determination of the Hazen-Williams coefficient *C* of the important feeder mains. The results of some of these tests are shown in the table.

It will be noted from the examination of this table that the mains laid in 1856 and 1897 had coefficients approximately equal to those given in the Hazen-Williams tables for pipe of this age; whereas the pipe laid between 1915 and 1934 and the raw water line cleaned in 1941 had coefficients that were approximately one-half the values given in the Hazen-Williams tables. Furthermore, the pipeline shown as No. 4, the oldest in the system and laid in 1856, had a higher coefficient than Nos. 6 and 7, which were laid in 1917 and 1922 respectively, and line No. 4 runs parallel to and between Nos. 6 and 7. Several theories have been advanced for this peculiar condition, such as the difference in the cast iron (the old pipe is much harder to cut), the difference in coatings used and the fact that the source of water was changed in 1913.

The raw water line (No. 3) was laid in 1913, and had a coefficient of 70 in 1941, prior to cleaning. Cleaning restored the coefficient to 125. This was reduced to 110 the first month, and to 57 by 1945.

Because of the low coefficients which existed in the distribution system, the report recommended the cleaning of 96,000 ft. of existing main. This includes 95 per cent of all mains 10 in. and larger, and about 70 per cent of the 8-in. mains in the existing system.

Due to the large amount of cleaning to be done, it was decided to spread the work over a period of about eight years, cleaning approximately 12,000 ft. of main each year. This will spread the cost over a long period. It is also hoped that subsequent cleaning will not

FIG. 1. 12-in. Pipe Laid in 1922 at Petersburg, Va.; $C = 40$, May 1945

FIG. 2. 12-in. Pipe Laid in 1856 at Petersburg, Va.; $C = 51$, May 1945

Item	Size, *in.*	Date Laid	Actual Coef. *C*	Hazen-Williams Coef. *C*
1	16	1897	58	70
2	16	1897	75	70
3†	16	1941*	57	120
4	12	1856	51	45
5	10	1915	45	90
6	12	1917	37	90
7	12	1922	40	90
8	8	1934	70	110

* Date Cleaned
† Raw Water Line

be required more often than every eight years. If this does prove to be the cycle required for cleaning, then the cleaning could be maintained by a continuous yearly program. The wisdom of this program must await the test of time.

Cleaning the Mains

In view of the extensive deficiencies indicated from the survey, it was considered necessary to proceed at once with the cleaning of the most critical feeder mains. It was decided that the most good would be accomplished by cleaning the mains shown as Nos. 4, 5, 6 and 7 in the above table. This gave a program totaling 12,000 ft. of 10- and 12-in. main. A contract for this work was let to the National Water Main Cleaning Company and the work was done during April and May.

The first lines cleaned were Nos. 6 and 7, which are 12-in. lines about one-half mile in length, laid on parallel streets about three blocks apart. Both were laid about the same time and each had a coefficient of approximately 40. The physical appearance (Fig. 1) of the corrosion in each was the same, and gave the same difficulty in cleaning. About 40 lb. of pressure was available to drive the cleaning machine, and this was not enough to drive the machine over about 1,000 ft. It was necessary in both cases to boost pressure with a fire engine to drive the machine through. From visual inspection, both lines appeared thoroughly clean, and about 4 to 5 cu.yd. of material was hauled away after cleaning each line.

The next pipe cleaned was No. 4, a 12-in. line running parallel to and between the two 12-in. lines above mentioned, and of about the same length. The coefficient of this pipe was 51. The physical appearance (Fig. 2) of the corrosion in this pipe was different from the other two; the tubercles were larger, further apart and much harder. The cleaning machine was driven through the pipe easily with 40 lb. of pressure, but visual inspection showed that the machine had failed to remove all of the corrosion. The cleaning machine was sent through the pipe a second time without trouble, removing about the same amount of corrosion as before. Inspection disclosed that only the top one-quarter or less of the pipe had been thoroughly cleaned, with some 60 per cent of the corrosion removed.

The last line cleaned was No. 5, a 10-in. line laid in 1915. This is the high-service pumping line and carries about 80 lb. pressure and has a velocity of 3.12 fps. for about twenty hours each day. The coefficient of this pipe was 45. The appearance of the corrosion in this pipe was different from the two previous types. The corrosion was harder and the tubercles were smaller but more numerous, probably due to the higher velocity of water passing through this line. The cleaning machine was driven through without great difficulty, negotiating seven 90-deg. bends. There was a slight delay when the machine stuck on a bad joint in the sixth bend, but a surge in the line was sufficient to free it. Inspection after cleaning showed the top half of the pipe thoroughly clean, but the bottom half varied—it was thoroughly clean at the spring line but none of the corrosion had been removed at the bottom of the pipe.

Results of Cleaning

By mutual consent of the city and the contractor, it was decided to complete the work on the mains not thoroughly cleaned, when the cleaning program is undertaken in 1946. The contractor plans to use a different type of scraper on the mains with the harder type corrosion.

Main cleaning is troublesome work, and much of Petersburg's was done at night. However, no great difficulties were encountered other than those previously mentioned. All pipe cuts were repaired with "Dresser" couplings. All services were cut off prior to cleaning and mains were flushed before resuming service. Only one service and two meters were stopped during the entire program.

Such severe corrosion of cast-iron pipe in such short periods of time was no doubt due to the chemical characteristics of the raw and finished water. Two years ago lime treatment was started as a means to combat this problem. The pH was gradually increased from an average of 6.4 to 8.0.

Last spring, before the main cleaning, an Enslow continuous stability indicator was purchased, and the pH value of the finished water is maintained at 8.6 to 9.3 to match the value shown by the indicator. The following table shows the pH, alkalinity and CO_2 values for the raw water and the finished water before and after the use of lime treatment.

	pH	Alkalinity *ppm.*	CO_2 *ppm.*
Raw	6.7–7.5	15–32	2– 6
Finished, before lime treatment	5.8–6.7	5–25	7–16
Finished, after lime treatment	8.6–9.3	22–36	0

There are not sufficient data available to report on the effectiveness of the lime treatment with the stability indicator at this time, except to say that about 90 per cent of the red water complaints, which were considerable prior to lime treatment, have been eliminated; and there was a reduction of about 75 per cent in stopped meters this summer. As a positive check on the value of the treatment it is planned to check the coefficient of pipes cleaned after one year's service. After a few more years of main cleaning and checking coefficients, more definite information on this subject may be available.

Acknowledgments

The author would like to acknowledge the helpfulness of the "Report on Water Distribution System, Petersburg, Virginia, 1945" prepared by E. Shaw Cole, Chief Engineer, The Pitometer Company, and the information and pictures furnished by J. A. Frank, Engineer, National Water Main Cleaning Company, who supervised the main cleaning.

Erratum

In "Standard Methods for the Examination of Water and Sewage—Summary of Recommended Changes for the Ninth Edition" (Jour. A.W. W.A., **37**: 1341 (1945)), *Part IV.—Bacteriological Examination of Water*, the words "crystal violet broth" were omitted. This paragraph should have read as follows:

"Tryptone glucose agar has been added as a plating medium, and lauryl sulfate tryptose broth for coliform test. *Crystal violet broth*, Fuchsin broth and formate ricinoleate broth have been deleted as confirmatory media. The schematic outlines have been revised, as has the section on coliform density. Bacteriological examination of water from swimming pools is included as a standard method. The Eijkman test has been added to the section on differentiation."

Water Waste Surveys

By H. E. Beckwith

Dist. Mgr., The Pitometer Co., Pittsburgh, Pa.

Presented on Nov. 9, 1945, at the Virginia Section Meeting, Roanoke, Va.

A SMALL privately owned water company in Pennsylvania used to have a large sign hanging over the cashier's window which announced that "OUR WATER IS FREE TO ANYONE WHO WILL TAKE HIS OWN PAIL TO OUR RESERVOIR." This sign pungently dramatized two truths. The first is that water in its raw state is a gift of nature and is normally without monetary value. The second point is that once this water is purified, being thereby manufactured into a usable product and delivered into the home, it bears definite items of cost which do give it a monetary value. That value is the price the customer pays for the water. The costs include wages, the cost of purification chemicals, the cost of fuel, the interest and depreciation on the money invested in filter plants, pumping stations, reservoirs, mains, etc. It is really quite remarkable that the cost of domestic water in the United States is usually only about ten cents per ton. This, mind you, is the cost of a manufactured product delivered where the customer wants it, when he wants it, and in the exact quantity he wants.

A little over a quarter of a century ago the author was employed by a dredging contractor operating in the tide water section of Virginia. We frequently purchased fresh water from "water boats," who made a business of hauling drinking water to ships in the harbor. As I recall it, the water was sold by the ton—$1.25 per ton. This is not an exorbitant price for hauling any commodity for a distance of several miles, but it amounts to more than $5.00 per 1,000 gal.

The ancient Greek historian, Herodotus, tells in his "History of the World" that Cyrus the Great would drink only water taken from a certain stream near his original home in the mountains. This water was hauled, throughout all his campaigns, on carts "in silver flasks, boiled, ready for drinking." One wonders at the purification and delivery cost of this water when figured at the point of consumption. This, incidentally, is possibly the earliest record of water treatment for the prevention of water-borne diseases.

So it is that the water which flows out of the tap in the kitchen or bathroom is not free—it is not free to the customer nor is it free to the authority charged with its purification and delivery to that tap. Every bit of that water represents a definite cost in labor and in money, and every drop that is wasted represents an actual monetary loss to someone. If the waste takes place inside the customer's meter, then the loss is his. But if it takes place before it reaches the meter, because of leaks on the mains or services, then the producing agency shoulders the cost.

As the contamination of sources of water supply spreads, purification costs mount, and pumping charges already are high. The unit cost of this waste is constantly increasing and with this increase comes a mounting pressure for the control or elimination of all preventable waste. The installation of meters for the control of fixture waste in the home is proceeding rapidly and more and more attention is being paid to the narrowing of the losses between the source of supply and the customers' meters.

There are several possible ways in which these losses can occur—there is leakage from the mains and services, under-registration of meters, fixture waste on unmetered services, unauthorized use from firelines or other connections to the system, wasteful public use of water and other special conditions which occasionally occur in individual instances. Any sysetm of water waste control which aims at 100 per cent results must be capable of locating all losses regardless of their nature.

In this country one of the best known systems of water waste control is the Pitometer Water Waste Survey. This system employs both direct and indirect measurements in such a way that during the course of the survey gagings are made of the amount of water leaving the system in sections of pipe as small as valves are available to segregate them. It is not good practice to attempt direct gagings on mains smaller than 4 in. in diameter, but by means of indirect measurements a determination of the loss from every piece of pipe in the system, regardless of size, is made. This point should be emphasized because a large number of persons seem to believe that it is impossible to use the Pitometer to determine losses from pipes too small to permit direct gagings. To all practical purposes it is just as easy to measure the losses from a ½-in. pipe as it is from a 6-in. or larger pipe. It is simply a matter of adapting the methods to the problem at hand.

Reduced to its barest essentials, a water waste survey amounts to this:

(1) Pumps are tested for slip or "wire-to-water" efficiency, depending on the nature of the pump. Master meters are checked for accuracy, and an independent measurement of the total use of water is made with the Pitometer. These tests provide a check on the figures for total consumption and often prove that the loss is greater or less than had been assumed. Particularly is this true in instances where there are no master meters and the consumption figures are based on the "rated" capacity of centrifugal pumps. If the actual pumping head is above the design head, the actual pumpage will be less than the "rated" amount. If the pumping head is less than the design head, the actual pumpage will be greater than the "rated" amount.

Other interesting things are often discovered in the course of these tests. In one instance a small suburban water company was buying water at whole sale through a Venturi meter. It so happened that this company had a large elevated storage reservoir, whereas the selling company had none. It was the custom to wash the filters with water taken back through the Venturi meter. A Venturi meter, however, is no respecter of the direction of flow. If water passes through such a meter, *regardless of the direction of flow,* it is added to the totalizer. As a result, this company was paying for the wash water twice—once when it went into the reservoir and once when it was

taken back to wash the filters—and never delivered the water to its customers.

(2) The entire distribution system is divided into districts which may vary in size from a mile or so up to several miles each. Each district is segregated by the closing of valves and a 24 or 48 hour gaging of the total use and of the variation of use in the district is made. Industrial meters are read during the test to determine how much of the total use in the district is of this character so that a determination of the net domestic use can be made.

(3) Wherever the preceding measurements indicate the possible existence of waste, indirect gagings are made to determine the distribution of the night rate of flow. These gagings are made after midnight and before five o'clock in the morning. All mains, regardless of how small they may be, are included in these measurements and the unit of test is as small as it is practicable to make it with the valves available. Manifestly, if there is no flow into a piece of pipe after midnight there can be no leakage. Where an appreciable flow is shown to exist, further investigations are made to determine the cause.

(4) Whenever the night flow measurements mentioned above show the possibility of leakage, the area included in the measurement is thoroughly combed to locate the cause of the flow. Various methods are used in making this investigation, but by far the largest number of leaks are definitely "tied down" through the use of sound amplifiers. It is at this point that these instruments are first used in the Pitometer system. They are not used to determine the possibility of leakage, but are used after measurements have shown that waste does exist.

(5) All large industrial meters are tested in place for accuracy and all unmetered lines, such as firelines, are checked with the Pitometer to be sure that no unauthorized use is taking place therefrom.

While it is clear from the above outline of the work that Pitometer surveys are based primarily on measurements, almost every type of sound amplifier is used to determine the exact place to dig for the leak. Aquaphones, geophones, stethoscopes and radio detectors are used. They are excellent instruments which have cut down the time and expense in making the spot location of the leak. Not so long ago it was necessary to drive bars to the main in order to determine the place to dig, and in some cases it is still necessary to do so. But in most cases either the geophone or the radio detector will enable the experienced operator to pin down the leak without driving bars. Care must be exercised in their use, as the author has known of cases where sparking motors, pressure regulating valves, etc., have given misleading results. The author was helping on a certain survey late in 1945. There were several measurements of the night flow into small sections of main where it was impossible to get any noise of leakage on valves or hydrants, or above the main. These particular mains were in alleys and the service lines were from 125 to 175 ft. long. By examining every one of these services it was found that several of them were broken, but so far away from the main that the noise did not carry back. The theory is that the measurements show the existence or non-existence of leakage in a certain piece of pipe. The resident engineer is allowed considerable latitude in the

means he employs in locating the source of loss—as long as he locates it.

Sometimes there is difficulty in locating the pipe so that tests can be made on it. Here, too, science has come to our aid. The new pipe locators are a real help. Speaking from personal experience, they have solved more than one knotty problem. There are two principal types. One works through direct contact, and a complete loop or circuit is made of which the pipe to be located forms a part. The sending instrument puts out signals which are picked up by a portable loop aerial connected to earphones when the aerial is held vertically above the pipe. When the approximate location has been thus determined, the aerial is held horizontally and a noise is picked up on each side of the pipe but a dead spot occurs directly above the pipe. The other type of instrument works by induction and requires no direct contact with the pipe. In this case the sending instrument puts out signals which are picked up by the pipe through induction when the instrument is properly placed. These signals are picked up by the receiving instrument in much the same way as in the case of the instrument using the direct contact. It must be remembered that this instrument will also pick up gas pipes and any other similar metal structures. Some instruments are so constructed that by the use of a switch either the direct contact or the induction method of location may be used.

So much for the field methods used. The remaining point to be touched on is the results to be expected from a survey of this kind. One of the most frequently asked questions is, "What percentage of our pumpage should we account for?" Unfortunately, there is no set answer to that question. Losses are not a matter of percentages. They depend upon the care with which the pipe was originally laid, the per capita use, the amount of use per mile of main, etc. There is one plant which sells 90 per cent of its water through its customers' meters. Yet, if its largest customer were to go out of business, the percentage would drop to 60 per cent. Many water works operators have been deluded during the war into thinking that their conditions were improving simply because their percentage of accounted-for water has improved as the war plants increased their use. If the losses were figured in gallons, instead of in percentages, they would probably find that there had been no material change unless they had taken positive action to reduce the losses. It is most unlikely that a plant with a per capita consumption of 40 gpd. will ever sell as high a percentage of its water as a plant with a per capita use of 150 gpd. Some plants will probably never be able to sell over 75 per cent of their pumpage but, on the other hand, there are some plants which sell through meters slightly over 90 per cent. The proper figure for each individual plant can be determined only after all sources of waste are located and eliminated.

Detecting Illegitimate Uses of Water

By William Stava

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Presented on Oct. 23, 1945, at the California Section Regional Meeting, Berkeley, Calif.

IN general, water works operators find that customers are honest. However, experience shows that from time to time some water user will attempt to increase the quantity of water delivered to his premises without a corresponding increase in his payment for the service furnished. While the title of the paper refers to this practice as "illegitimate use of water," the more common and appropriate term is "stealing."

The most simple and probably the most common and frequently used method of obtaining an additional supply of water, with the hope of not increasing the bills, is by conveying it through a hose from a neighboring premises, either with or without the neighbor's consent. On a system having flat rates a customer will have the service discontinued under the guise of vacating the property, but will obtain water by means of a hose from a cooperative neighbor. In other instances, after the service has been shut off he will turn it on again and continue to reside on the premises. However, a check of the service and the residence by a service man will determine whether or not the service is active, or if the property is still occupied. The regular survey of premises throughout the system for checking the flat rate charges for service rendered is also helpful in maintaining honesty among the few customers who are inclined to be dishonest.

On a metered system, a customer will sometimes attempt to supply water to a neighbor through a hose connection or a pipeline. As an example of this practice, one utility found itself supplying ten houses in another utility's territory. An extension had been made from one of its customer's premises, and apparently with his knowledge, to serve a portion of a housing project that could not be served at that time by the adjoining water system. As new houses were added to the project, the meter registration increased each month to such an extent that the meter reader asked for an investigation of the service which disclosed the unlawful extension. The bills were all paid by the customer, but he claimed that he had no knowledge of the installation.

If the water deliveries at any service become excessive or subnormal, the meter reader will probably spot the unusual condition and report it for investigation. People who dislike seeing their neighbors get something for nothing often report multiple services.

In summer resort communities, it may happen that premises are not occupied continuously but service is turned on throughout the season of the year. A few residents may amplify their water supply by pilfering from an absent neighbor's premises via the hose

route. It is difficult to detect this type of petty thievery, and it is more difficult to explain the charges for the unaccounted-for water to a customer who probably only visits his cabin on week ends. A valve installed on the house pipe in a locked basement is the best protection against this type of nuisance.

A more uncommon situation occurs when a customer has access to an abandoned live service or a pipeline and also has a lawful service connection. In such an instance the premises usually have a garden or a lawn, or both, that require more water to maintain than is shown by the meter registration. The meter reader will be the first to suspect another source of water supply, and if the premises have no well or spring sources, a search should be made for an illegal connection with a pipe locator.

There have been several instances reported involving customers receiving water in one zone and then unlawfully connecting to a pipeline or a service supplied from an upper zone at higher pressure. Each offender was surprised and chagrined to be informed by the utility, after the first meter reading, that he had an illegal service connection. The location of the service was pointed out and it was shown that the meter had been running backward for a month, which pointed to the extra source of water. The connections were found with a pipe locator.

Tampering With the Meter

Reversing the meter is also tried by customers seeking to increase the water supply at the expense of the utility. The low use of water as compared to the size of the lawn or garden, or size of the residence, will usually be noted by the meter reader. He will also normally see evidence of the meter having been removed. Sealing the meter couplings usually stops this practice.

Another favorite method of reducing meter readings is to file out alternate teeth from either the driver or the change gears, which are located just below the meter dial. The loss of these teeth will cause the meter to register slow. However, the low registration will usually be detected by the meter reader, as the premises will indicate a much larger use of water. The meter reader can usually spot any tampering with the register and sealing it will normally stop the practice. However, it should be noted that the seal can be disconnected by working the wire through it, and it can be replaced in such a way that the tampering can only be detected by a careful inspection of the seal. As some utilities make it a practice to replace meters at regular intervals, the loose seals are discovered in the shop. The customer is informed of the discovery, which usually stops his activity along these lines.

Customers have also been known to eliminate an unusually high meter registration by smashing the meter dial and blaming it on mischievous boys in the neighborhood. This method may also be employed by irate customers in avenging a real or a fancied wrong charged to the utility. Employees of the utility itself have also been known to wreck meter dials in order to cover up errors and omissions in reading meters. It is extremely difficult to fix responsibility for the leakage or meter damage unless the party is caught in the act of breaking the dial.

The installation of a jumper, to replace the meter for a portion of the month, is sometimes resorted to in an effort to reduce the monthly water bill. An observing meter reader will usually detect this method of thievery, as

the marks of the pipe wrench are easily detected on the brass meter. The use of sealed meter couplings also acts as a deterrent against this practice.

Bypassing the meter on a domestic service is still being tried to some extent. However, it was more prevalent during the prohibition era when it was a standard practice with the bootlegging gentry. Stills were erected in residences and the meter was bypassed in order to avoid detection through the excessive use of water. The bypass was usually well constructed and was equipped with a gate and check valve. It was installed at a sufficient distance from the meter so that it would not be located by normal digging when an attempt was made to find it, or it might even be installed deep under the meter which made it still more difficult to locate. The bootlegger type of user was usually exposed and reported by neighbors and the service was then checked for a bypass with a pipe locator.

Cross-Connections

Occasionally industrial customers attempt to effect a saving in water charges or, as a matter of convenience, to supply certain water facilities, by installing cross-connections to the fire service mains in the plant. This practice can be carried on successfully when the fire services are not protected by meters or detector check valves. Where protective devices are not installed, a utility representative should inspect the fire lines throughout the plant at regular intervals. However, the standard method of protecting a fire service is by the use of a detector type meter or a bypass check valve with pressure alarm system.

Where an illegal use of water from a fire service is suspected, the detector check valve may sometimes be bypassed with a meter without attracting the customer's attention. Any water used thereafter from the fire main will be registered. If time of use and quantity of water delivered are desired, a chart recording register may be installed. A pitot tube installed in the fire service line may also be used as a detector of water flow, and, together with a recording chart, the time of use and quantity of water delivered may be obtained.

Carelessness

There are instances when the customer's carelessness or the failure of some of the facilities discloses illegal use of water. A customer in an unsuccessful legal contest with a utility decided to even matters by obtaining free water from its main. He caused a tunnel to be dug under the street, a connection to be made to the main, and an elevated tank and windmill to be erected on the premises. The windmill was operated at intervals but the tank was filled from the main and service was obtained without cost for about twenty years. However, one day a utility employee noticed the tank overflowing, but the windmill was not operating, and he reported the unusual condition. An inspection of the premises disclosed the illegal connection and also the fact that the float valve at the tank had failed to operate.

Illegal Practices in Desert Areas

In rural and desert areas, where water is expensive and difficult to obtain, it is a common practice for residents of outlying districts to obtain water from the fire hydrants of the nearest town water system. The water may be withdrawn either during the day or the night, and, of course, with-

out any authorization from the utility. This withdrawal causes a surge in the mains, by reason of the fast opening and closing of the hydrant, and can usually be detected on a recording pressure gage chart even if located many blocks away. The quantities of water lost by this method are nominal but the hydrant nut and stem are usually damaged by the culprit who uses a pipe wrench in opening and closing the hydrant.

Dripping is another method practiced in some localities to defraud the water utilities. This is accomplished by allowing a faucet to drip at a rate that is too slow to operate the meter disk. It is reported that approximately thirty gallons of water a day can be delivered in this manner through a meter without registering. In a small desert town where water is delivered at a rate of approximately one cent a gallon, dripping is such a popular pastime that it is said to have seriously affected the utility's earnings. Some of the meter companies produce a "gulper" to control dripping. This gadget is installed ahead of the meter and only releases the water when the storage chamber is filled. This quantity of water will operate the meter.

The irrigation service furnished by the Los Angeles Water Department in the San Fernando Valley during the early days developed several problems involving the unlawful use of water. Pressure service was supplied to the farmers through impeller-type meters, and water was usually delivered into a standpipe for distribution through irrigation pipelines. One of the favorite pastimes of the farmers in attempting to reduce water bills was to drill a hole through the side of the standpipe, insert a rod through the service pipe into the meter and strip the vanes from the impeller. Another playful activity engaged in by the farmers was knocking the registers off the meters. This latter problem was solved by the Neptune Meter Company, which installed a second register inside the meter top, so connected that both registers recorded the water delivered. When the top register was destroyed, the second one still had a record of the water consumed.

Conclusions

In analyzing the various unlawful practices used in obtaining water from utility pipelines, it must be concluded that they all are more or less petty and not always of great consequence in so far as loss of revenue is concerned. It is also apparent that they may be more or less easily detected with the aid of protective equipment and by intelligent and alert utility employees, particularly the meter readers. It is essential, however, that the illegal use of water be kept at a minimum as a matter of principle, and in order to demonstrate to dishonest customers "that crime doesn't pay."

Milestones in Taste and Odor Control

By W. A. Welch

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Presented on Nov. 9, 1945 at the Virginia Section Meeting, Roanoke, Va.

MY first recollection of concern for water quality takes me back to a small town in a neighboring state where, as a boy of eight years, I found it a wonderful experience to be able to turn on the tap and draw water inside the house rather than go out to the rain barrel or cistern. Of course, it was irritating at times to have the water come out of the tap the color of coffee and then to have to wait several minutes until the mud settled sufficiently for the water to be usable. Our family got around this handicap most of the time by beginning to draw water in all available utensils as soon as a rain storm had started. In this way we would have the advantage of getting the water that had already settled in the reservoir before it became contaminated with mud that would be pumped from the river as a result of heavy rain.

I cannot remember clearly just how this water tasted because the most important thing at that time was to have it clear. However, I do remember that several people in the town did not depend upon the municipal supply for drinking water and, during the fall of 1917, there were 29 fatalities from typhoid fever, among them my father, in a town with a population of only 8,500. I have no figures on the actual number of typhoid cases, but the "city water" was chlorinated and no doubt the epidemic was caused by using palatable and more attractive water from questionable sources.

Naturally, the supply referred to is now filtered, chlorinated and treated with activated carbon for taste and odor control.

This is an illustration of the comparatively short time that has elapsed since the public more or less resigned itself to accepting unattractive and unpalatable water. After all it was a lot more convenient than going out to the cistern to obtain water of questionable bacteriological quality.

As recently as 1928 I crossed the Kanawha River in West Virginia via an auto ferry consisting of a small tug boat towing a barge. In midstream, I noticed the "engineer" of the barge scoop into the river with a long handled dipper and take a swig of the muddy water. When I cautioned him about the potential hazard of drinking this water, his reply was somewhat to the effect that he did not believe in all these new-fangled methods of treatment because they took all of the strength out of the water. Fortunately, the attitude of the general public is not reflected by the remarks of this mountaineer who had been drinking such water for "nigh on 50 years."

Public opinion regarding quality becomes more critical in geometric proportion. That is to say, the more improvements that are made the greater the improvement desired. When fil-

tration removed all suspended matter from water supplies, and chlorination made such supplies safe from a bacteriological standpoint, the general public naturally expected to have the water taste better because it looked as if it *should* taste better and they knew it was safe to drink. Even slight improvements in taste were worth while, but any improvement that was made acted as a check against backsliding to the old standards of palatability. In other words, any taste and odor control measure represents a step forward from which it is impossible to slip backward without arousing public criticism. As one Michigan operator expressed it to me when I made a remark about what seemed to be a high dose of activated carbon, "Brother, I've got a bear by the tail and I can't let go."

Tastes and odors of water are peculiar phenomena when compared to tastes and odors of other food products. Let us compare objectionable tastes and odors to a weed. A weed is defined as any plant growing where it is not desired. Thus, an orchid in a corn field would be classified as a weed.

People have learned to accept characteristic tastes and odors in characteristic places. Thus, they will relish fresh cucumber in a salad, but they cannot be depended upon to enjoy the cucumber taste of synura in a water supply. Nothing tastes more like green algae than watermelon. The flavor is delicious when found in watermelon, but please be cautious about permitting it to get into your distribution system.

Thus, when we measure the odor of water, we are not measuring it for desirable odors, but for the absence of odors. No odor is desirable in water because water and air are nature's only life-sustaining products that do not possess a characteristic taste and odor. Therefore, can we blame the layman if he assumes water is contaminated because it has a bad odor?

Prior to the early 1920's the water works operator was handicapped by the lack of tools to remove tastes and odors and was further handicapped by the lack of scientific methods to evaluate the efficiency of these tools even if they had been available.

In the middle twenties, work was progressing on the use of granular activated carbon for taste and odor removal. This was shortly followed by experimental and plant scale work on the use of powdered activated carbon. At the turn of the decade there were some eight or ten plants throughout the country using powdered activated carbon with a measurable degree of success. The acceptance of powdered activated carbon during the next three years might be called phenomenal. At least here was a tool with which results could be obtained in controlling tastes and odors and the word spread throughout the water works profession with amazing rapidity. Actually, in view of later experiences, some of the claims that were made by enthusiastic users of activated carbon now look ridiculously exaggerated. However, such exaggeration may have been justified when we remember that this was the first step in taste and odor control and first steps do look awkward after one has learned to walk. Also, the evaluation of early results was more or less an expression of opinion by various individuals. They could have an opinion that the water was a good deal better, but there was no numerical method for accurately expressing just how much better.

The development and subsequent refinement of the threshold odor test now

gives one a ready means of judging the efficiency of any method of taste and odor control. The object of this test, of course, is to determine how much dilution of the sample with odor-free water is necessary before the analyst fails to distinguish the characteristic taste and odor in the water being tested. Since this test is run at a temperature of 65°C., the analyst is given a "safety factor" of sensitivity over the consuming public. That is, any odor at the threshold point at this temperature would certainly not be noticed in the finished water by laymen who are not consciously looking for a taste or an odor.

The question of what tolerable threshold odor can be acceptable to the consuming public has arisen. Of course, the ideal situation is to produce a finished water having a threshold odor of 1, but obviously this is not practical in the treatment of most raw water supplies. A number of authorities have advanced an arbitrary figure of 2 as a satisfactory threshold odor and we agree unquestionably that any water having a value of 2 or less would approach perfection.

Nevertheless, an arbitrary figure set up in one case could not apply in another case because of the difference in the characteristics of the objectionable tastes and odors. The author has himself run across plants that were turning out a very palatable water with a threshold odor value as high as 6, but on the other hand, only recently I have come across a water with a threshold odor value of 4 that was almost nauseating. In the latter case, a really palatable water was not obtained until this value was brought from 4 down to 1.9.

It would be very nice, from an operating standpoint, if we could say that a raw water having a threshold odor value of 50 could be reduced by a specified dose of this or that chemical to a value of 2 or less. When using any method of taste and odor control, however, it is impossible to set up an arbitrary figure for the quantity of corrective chemical because the dosage is dependent upon too many factors and must be worked out in each individual plant.

The intensity of odor in the raw water has very little to do with the amount of treatment needed. In a number of cases, a raw water having a threshold odor of 50 is much easier to bring to a point of palatability than a raw water having a value of 8 or 10. Perhaps the main reason for this is the nature of the objectionable odor, but other reasons to be considered are the means employed for taste and odor control as well as points of application and other treatments involved in purification.

Therefore, each individual operator should instigate a routine plant survey with regard to tastes and odors and in times of severe conditions should conduct tests twice daily or even more often in order to apply corrective measures before water with an objectionable odor has been pumped into his distribution system.

The threshold odor test not only serves as a means for controlling plant operations, but also serves as a means of evaluating the efficiency of various methods for controlling tastes and odors.

So far, only activated carbon has been mentioned because it was the first tangible method introduced for taste and odor control. Since the introduction of activated carbon and the subsequent attention that has been brought about in controlling tastes and odors,

there have been other methods advanced, such as ozonation, break-point chlorination and, more recently, chlorine dioxide.

In any method of control it is realized that the last traces of tastes and odors are the most difficult to remove. For example, if activated carbon is being fed to a raw water having a threshold odor of 20 this may be brought down to a value of 8 with the first 10 lb. of carbon applied, while the next 10 lb. may bring it from 8 down to 4 and the next 10 lb. from 4 down to only 2. Now if it is desired to bring this water down from a value of 2 to 1.4 it may take as much as 20 or 30 additional pounds of carbon which, of course, might be considered uneconomical in view of the slight improvement effected. In other words, one reaches a point of maximum odor removal where the feeding of more carbon is of little or no benefit. This point is dependent, to a large extent, on the nature of the carbon being used. At one large city, it was desired to reduce the threshold odor value to 3 or less. With the feeding equipment available for applying carbon they could not feed a dose large enough to reach this value. However, upon switching to a carbon that had been activated in a different manner, the point of maximum adsorption was extended and it was easily feasible to feed the dose required to reach the desired threshold point.

Conclusion

The general public desires and expects palatable water at all times and in order to insure the delivery of such water there are now available means of control as well as an accurate means for evaluating treatment in the plant. It is urged that the individual superintendents and operators avail themselves of the opportunity to prevent trouble by anticipating it in advance by means of the threshold odor test as a routine check for preventing odors from escaping through the plant and into the distribution system.

Anaerobic Corrosion of Steel Pipe Due to Nitrate

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A contribution to the Journal

INVESTIGATION of the cause of serious red water complaints at a Navy station in California revealed the rapid corrosion of a 2.5-mile steel main delivering water to the station from two deep wells. The investigation also disclosed an abnormally high chlorine demand of the delivered water due to the presence of ammonia and nitrite not found in the well water. Analyses of the well water showed that these abnormal conditions were related primarily to the high nitrate content, which in the absence of dissolved oxygen served as a cathodic depolarizer in the corrosion reaction and resulted in appreciable concentrations of nitrite, ammonia and ferrous hydroxide in the delivered water.

The purpose of this discussion is to describe the conditions found, the conclusions drawn therefrom and the steps taken to a satisfactory solution of the problem.

Theory

Anaerobic corrosion of ferrous metal is possible in strongly acid solutions or when a chemical is present in the solution which can react at the cathode surface. Nitrate is an example of such a chemical. In this reaction nitrite ion, ammonia and hydroxyl ion are formed at the cathode while ferrous hydroxide is formed at the anode. Although nitrate is a less powerful depolarizer than oxygen the absence of the latter prevents the formation of a film of insoluble hydrated ferric oxide at the anode which allows the attack to progress much further than under oxygen depolarization.

There are lacking in the literature references to actual cases where nitrate ion has been the cause of internal pipe corrosion. Evans (1) gives two references (2, 3) which cite cases where nitrate ion has been responsible for the anaerobic corrosion of steel surfaces in soil. In both these instances the reaction may have been accelerated or even made possible by nitrate-reducing bacteria. Hadley, in discussing a paper by Thomas (4), points out that no definite proof has as yet been offered demonstrating the indispensability of bacteria in this corrosion reaction. Larson (5) has described a water supply in Illinois which is corrosive in dead ends where dissolved oxygen is absent. The supply contains an appreciable amount of ammonia which is subsequently oxidized to nitrite and nitrate with loss of dissolved oxygen. In anaerobic sections of the distribution system, nitrate and nitrite previously formed are reduced, while the iron content of the water is increased

to as much as 8 ppm., producing red water. Larson attributes these changes to anaerobic bacterial action.

Regardless of whether or not nitrate-reducing bacteria play an important part in the anaerobic corrosion of steel pipe, the overall reactions may be written as on page 63: *

Conditions necessary for these reactions to occur are: (1) the presence of nitrate ion, (2) the absence of dissolved oxygen, (3) a low pH and (4) possibly the presence of nitrate-reducing bacteria.

Nitrate is present in some amount in many domestic water supplies in the United States (6). If the nitrate content is high, these supplies, if devoid of oxygen, may present a corrosion hazard more acute than if the same water were aerated, due to solubility of the anodic corrosion products in the absence of dissolved oxygen. Such a case occurred at the Navy station already mentioned.

* The direction and driving force of a chemical reaction can be determined from the potential or E value for that reaction. A positive E value indicates that the reaction will progress as written, while for a negative value the reverse is true. The standard potential for Eq. (1) can be computed from data furnished by Latimer (7) and is found to be 0.887 v. In a similar manner the standard potential for Eq. (2) is found to be 0.777 v. Thus, following the usual procedure, it can be computed that for concentrations of reacting substances sometimes encountered in practice both of these reactions possess a strong tendency to progress as written. It may be of interest for comparison with the above potential values to point out that a standard potential of 1.278 v. is given for the usual corrosion reaction involving dissolved oxygen.

$$2Fe + O_2 + 2H_2O \rightarrow 2Fe(OH)_2$$

Under conditions normally encountered, i.e., 8 ppm. oxygen in water solution, the E value becomes 1.273 v.

Conditions at Navy Station

Water for the Navy station is derived from two deep wells and is pumped to the station through 12,000 ft. of 8-in., unlined, light-gage, steel pipe. Water from the well field was pumped into the pipeline for the first time on Apr. 18, 1945. Severe corrosion was evidenced immediately by an obvious increase in color in the water after passing through the pipeline.

Chemical analyses of the water from the two wells are given in Table 1. It will be noted that they are similar and normal in chemical composition except that each contains appreciable free carbon dioxide which, in conjunction with moderate alkalinity, imparts to each a low pH value. High bacterial counts indicate organic contamination. For comparative purposes these analyses are averaged and recorded in part in Column (1) of Table 2.

TABLE 1

Analyses of Well Waters

Analysis	*Well No. 1* (*150 gpm.*) (*ppm. except pH*)	*Well No. 2* (*70 gpm.*)
Sodium (Na)	25.3–32.8	26.6–32.4
Magnesium (Mg)	13.3–15.3	12.5–14.0
Calcium (Ca)	25.7–31.0	28.1
Chloride (Cl)	61.2–64.0	56.1–58.0
Sulfate (SO_4)	30.1–30.2	34.2–38.7
Bicarbonate (HCO_3)	83–100	85–87
Alkalinity ($CaCO_3$)	68–82	70–71
Dissolved Oxygen (O)	0	0
Total Dissolved Solids	252–276	239–260
Hardness (Calc.) $CaCO_3$	120–145	118–135
Hardness (Soap) $CaCO_3$	129–133	129
Iron (Fe)	0.1–0.2	0.1
Manganese (Mn)	0–0.1	0–0.1
Silica (SiO_2)	25–35	25–30
Turbidity	11–35	3–14
Color	0	0
Ammonia (N)	0.025	0.025
Nitrate (N)	4.0–7.0	4.0–7.0
Nitrite (N)	0.017	0.015
pH	6.4	6.4

$$Fe \rightarrow Fe^{++} + 2e$$
$$Fe^{++} + 2H_2O \rightarrow Fe(OH)_2 + 2H^+ \qquad \text{Anode Reaction}$$
$$NO_3^- + H_2O + 2e \rightarrow NO_2^- + 2OH^- \qquad \text{Cathode Reaction}$$
$$Fe + H_2O + NO_3^- \rightarrow Fe(OH)_2 + NO_2^- \qquad \text{Over-all Reaction} \qquad (1)$$

$$Fe \rightarrow Fe^{++} + 2e$$
$$Fe^{++} + 2H_2O \rightarrow Fe(OH)_2 + 2H^+ \qquad \text{Anode Reaction}$$
$$NO_3^- + 6H_2O + 8e \rightarrow NH_3 + 9OH^- \qquad \text{Cathode Reaction}$$
$$4Fe + 6H_2O + NO_3^- \rightarrow 4Fe(OH)_2 + NH_3 + OH^- \qquad \text{Over-all Reaction} \qquad (2)$$

Column (2) of Table 2 is a partial analysis of the water after passing through the pipeline. By comparing this analysis with that shown in Column (1) it is apparent that the iron content is considerably greater, that some of the nitrate has been reduced to nitrite and ammonia, and that the turbidity and color are higher. About the time this sample was collected the laundry reported excessive iron staining of white fabric and ferric hydroxide floc was observed dispersed throughout the water in the reservoir.

Additional samples at the end of the pipeline were collected on subsequent dates. Analyses of these samples are shown in Columns (3)–(5) of Table 2. These data support the theory of the corrosion reaction given above. Iron increased from 0.1 ppm. to as much as 12.5 ppm. Nitrate has been reduced to yield a maximum of 0.3 nitrite nitrogen and 1.0 ppm. of ammonia nitrogen.

Corrective Treatment

An examination of either Eqs. (1) or (2) indicates that the reaction rate can be reduced by increasing the hydroxyl-ion concentration, i.e., the pH of the water, or by removal of the nitrate ion. For the reason given above, it is believed that aeration would also reduce the corrosion rate; however, no tests to prove this were undertaken.

Supplemental treatment with chlorine may be required to eliminate bacterial reduction of nitrate.

Field Experiments

A small chemical solution feeder was installed to deliver chemical directly into the well. Sodium carbonate was used in the preliminary tests in preference to sodium hydroxide or calcium hydroxide because of convenience in handling. Sufficient chemical was added to raise the pH to 8.0. The actual weight of chemical added corresponded closely with the calculated weight required.

Columns (6) and (7) of Table 2 are analyses of the treated water taken from the far end of the pipeline after treatment with sodium carbonate. That the corrosion reaction was completely arrested is indicated by the results of tests for iron, turbidity, color, nitrite and ammonia, all of which approximate the values of the raw water.

It is apparent, however, that nitrate reduction has not been entirely elimi-

TABLE 2

Water Analyses Before and After Corrective Treatments

	Sample Collected Before Passing Through Pipeline	Samples Collected After Passing Through 12,000 ft. of 8-in. Steel Pipe						
	(1)	(2) 4/17/45	(3) 5/4/45	(4) 5/10/45	(5)* 5/22/45	(6) 5/24/45	(7)† 5/26/45	(8) 6/13/45
Total Dissolved Solids	250	250	—	—	298	353	372	343
Alkalinity ($CaCO_3$)	75	—	—	—	85	164	176	140
Dissolved Oxygen (O)	0	0	0	0	0	0	0	0
Turbidity	10	28	—	21	23	8	8	14
Color	0	30	—	90	25	0	0	15
pH	6.4	—	—	—	6.4	8.0	8.3	7.3
Calcium Carbonate Saturation Index (25°C.)	−1.6	—	—	—	−1.6	+0.1	+0.4	−0.5
Ammonia (N)	0	0.7	0.4	1.0	0.3	0.3	0.2	0
Nitrite (N)	0	0.3	0.3	0.3	0.2	0.2	0.1	0
Nitrate (N)	5.0	3.6	3.2	1.6	3.2	5.0	7.0	4.5
Iron (Fe)	0.1	12.5	6.3	8.8	2.0	0.1	0.1	0.3

* Na_2CO_3 added at suction of well pump beginning May 23, 1945.
† Chlorine and Na_2CO_3 added at suction of well pump beginning June 2, 1945.

nated in spite of the fact that corrosion of the steel pipe has apparently been stopped. Column (8) is an analysis of a sample of water collected from the end of the pipeline during a period when treatment with sodium carbonate was supplemented with chlorination. The chlorine dosage was sufficient to produce a residual of 0.5 ppm. of free chlorine at the station. The reduction of nitrate was stopped entirely by this treatment.

The addition of chlorine at the well eliminated a slight chlorinous taste which was apparent when chlorine was added at the station end of the pipeline.

Conclusions

The mechanism of the anaerobic corrosion of steel pipe in the presence of nitrate ion is outlined.

The history of a particular case involving a water devoid of dissolved oxygen, having a pH 6.4, and containing 4 to 7 ppm. nitrate is described. The corrosion reaction released 9.0 ppm. of ferrous iron. Raising the pH to 8.0 completely arrested the corrosion both in the presence and absence of chlorination.

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Industrial Requirements for Water

By Harry E. Jordan

MANY individuals have occasion to ascertain the quantity of water required for industrial processes. A smaller number are inclined to express these requirements in terms of the unit of the product derived from the industry and a still smaller number record this information in a form which is available publicly. During the war, many expressions of water quantity requirements have been published in one place or another. Some months ago, certain preliminary figures were drawn together in the News of the Field section of the JOURNAL (September 1945). Various communications have been received since that time which have made it possible to check the figures originally published as well as to add to them. Items in the following tabulation which bear no identifying number are derived from "Supplement D—Industrial Waste Guides," which is a part of the report of the U.S. Public Health Service on a survey of the Ohio River and its tributaries for pollution control. Table 1 of that report is a summary of waste discharge per unit of production. It has been taken for the purpose of this tabulation to report the quantity required per unit produced.

Other sources of information contributing data to this tabulation are as follows:

1. News of the Field, Jour. A.W. W.A., **37**: 4 (1945).
2. George J. Natt, New York Public Service Commission.
3. Confidential sources not named.

It appears that the figures which are listed herewith are more likely to relate to normal requirements (plus waste) than to the absolute minimum requirements. The question relating to the most efficient use of water is particularly emphasized in the quantity related to the airplane engine. It appears reasonable to assume that the 125,000-gal. figure does not necessarily represent water used only once and afterward discharged, but rather the amount of flow-through water circulated in the engine during the period of the test, which would be subjected afterward to temperature adjustment and re-use. In other words, it appears proper to assume that intelligent conservation methods in various industrial processes listed would not only reduce the quantity of water required per product but would also reduce the quantity of polluted water discharged to the streams or the quantity of material for which sewage or waste treatment has to be provided.

Incidental to the development of these figures, a very interesting statement was derived from George J. Natt, Assistant Hydraulic Engineer of the New York State Public Service Commission, which had to do with the quantity of water required on a battery-type poultry farm. The data are not of major industrial significance, but the details are of interest to water works men. This statement follows:

The investigation we made concerned the rate being charged the establishment by the local water company, it being on a

Industrial Requirements for Water

Product	*Unit Produced*	*Water Required gal. per unit*
Airplane engine (1)	to test	50,000–125,000
Alcohol (1)	gal.	100
Aluminum (1)	lb.	160
Aviation gas (1)	gal.	7–10
Brewing:		
Beer	1 bbl.	470
Whiskey (1)	gal.	80
Buildings:		
Office (1)	person	27–45 (per day)
Hospital (1)	bed	135–350 (per day)
Hotels (1)	guest room	300–525 (per day)
Laundries (1):		
Commercial	lb. "work"	4.3–5.7
Institutional	lb. "work"	3
Restaurants	meal	0.5–4.0
Butadiene (1)	lb.	160
Canning:		
Apricots		8,000
Asparagus		7,000
Beans:		
Green		3,500
Lima		25,000
Pork and		3,500
Beets		2,500
Corn		2,500
Grapefruit:		
Juice	100 cases No. 2 cans	500
Sections		5,600
Peaches, Pears		6,500
Peas		2,500
Pumpkin (squash)		2,500
Sauerkraut		300
Spinach		16,000
Succotash		12,500
Tomatoes:		
Products		7,000
Whole		750
Cement (1)	ton	750
Coke	100 tons	360,000
Distilling, grain:		
Combined wastes		
Thin slop	1,000 bu. grain mashed	600,000
Tailings		
Evaporator condensate		
Distilling, molasses	1,000 gal. 100 proof	8,400
Distilling, cooling water	1,000 gal. 100 proof	120,000
Electric power (1)	kw.	80
Explosives (1)	lb.	100 plus
Gasoline (1)	gal.	7–10
Iron ore (brown ore) (3)	ton	1,000
Meat:		
Packing house	100 hogs killed	550
Slaughterhouse	100 hogs killed	550
Stockyards	1 acre	160

INDUSTRIAL REQUIREMENTS FOR WATER—*Continued*

Product	*Unit Produced*	*Water Required gal. per unit*
Milk:		
Receiving station	1,000 raw lb.	180
Bottling works	1,000 raw lb.	250
Cheese factory	1,000 raw lb.	200
Creamery	1,000 raw lb.	110
Condensery	1,000 raw lb.	150
Dry milk factory	1,000 raw lb.	150
General dairy	1,000 raw lb.	340
Oil, edible (1)	gal.	22
Oil field	100 bbl. crude	18,000
Oil refining	100 bbl.	77,000
Paper:		
Paper mill	1 ton	39,000
Pasteboard	1 ton	14,000
Strawboard	1 ton	26,000
Deinking	1 ton	83,000
Paper pulp:		
Ground wood	1 ton dry	5,000
Soda	1 ton dry	85,000
Sulfate	1 ton dry	64,000
Sulfite	1 ton dry	60,000
Poultry (2)	1 bird	1 (per day)
Rail freight (3)	ton-mile	0.1
Records (3)	1 disc	2.4
Smokeless powder (3)	ton	50,000
Soap factories (1)	ton	500
Steam power (3)	ton of coal	120,000–60,000
Sugar refineries (1)	lb.	0.5
Tanning:		
Vegetable	100 lb. raw hide	800
Chrome	100 lb. raw hide	800
Textile:		
Cotton:		
Sizing	1,000 lb. processed	820
Desizing	1,000 lb. processed	1,750
Kiering	1,000 lb. processed	1,240
Bleaching	1,000 lb. processed	300
Souring	1,000 lb. processed	3,400
Mercerizing	1,000 lb. processed	30,000
Dyeing:		
Basic	1,000 lb. processed	18,000
Direct	1,000 lb. processed	6,400
Vat	1,000 lb. processed	19,000
Sulfur	1,000 lb. processed	5,400
Developed	1,000 lb. processed	14,400
Naphthol	1,000 lb. processed	4,800
Aniline black	1,000 lb. processed	15,600
Print works	1,000 lb. processed	4,500
Finishing	1,000 lb. processed	6
Knit goods (1)	lb. bleached	8
Rayon manufacture	1,000 lb. produced	160
Rayon hosiery	1,000 lb. produced	9,000
Woolens	1,000 lb. finished	70,000

flat rate basis. The poultry farm was a rather scientifically operated affair, in connection with which there was a freezing locker, refrigerator room, slaughtering room and another room in which eggs were sorted and crated—all in addition to the buildings in which the chickens were housed. The chickens were never allowed to run free, but each bird was housed in a separate pen with the pens being stacked four high and about eight long, with tiers placed back to back. For drinking purposes, the piping was arranged between the tiers with an automatic fixture serving four coops. The fixture was inverted and controlled by a small, steel ball which always seated itself and permitted only a drop of water to be suspended. The birds were trained to use this fixture and each peck at the steel ball would permit of the discharge of another drop of water.

There were in all, normally, 15,000 chickens housed at the farm, about 10,000 of which were laying hens and the remainder broilers. In our investigation of the rate, while we had various figures as to the estimated amount of water a chicken would drink per day, we concluded that an estimate of 1 gal. per bird per day would be reasonable, considering the over-all water usage at the farm. It was noted during our inspection that considerable water was used for washing the slaughter room after each period of operation, and that the rooms housing a considerable number of birds were washed down completely after the chickens had been removed to an adjacent building.

Since the owner apparently was not satisfied with the conclusions that were reached, he agreed to place meters at the farm so that the entire consumption could be accurately checked. At the end of one year's operation these meters showed that the entire consumption for the farm was 5,329,000 gal., which sustained our estimate of 1 gal. per chicken per day.

Additional documented data concerning water use requirements are desired and it is hoped that readers of this JOURNAL will provide further information.

Reconditioning of the Rochester Conduit

By Lewis B. Smith

Supt. of Water, Dept. of Public Works, Rochester, N.Y.

Presented on May 22, 1945, at the New York Section Regional Meeting, Rochester, N.Y.

BY an act of the legislature, Chapter 754 of the laws of 1873, the city of Rochester was authorized to enter upon, to control and to use Hemlock and Canadice Lakes, 30 mi. south of the city, for the purpose of securing a water supply, and to take such measures and make such constructions as would be necessary to secure said water for the purpose intended.

In 1874 a contract was let for the construction of a compound conduit. This contract consisted of approximately 50,000 ft. of 36-in. wrought-iron pipe, about 15,000 ft. of 24-in. wrought-iron pipe and 81,000 ft. of 24-in. cast-iron pipe.

The specifications for the wrought-iron pipe called for Class C No. 1 shell iron pipe of the best quality manufactured and on sale in the market and acceptable to the chief engineer of the water works. Specified thickness was No. 7 of the Birmingham wire gage, or about $\frac{3}{16}$ in. Each sheet or plate was to be rolled to a width of 5 ft. and a length sufficient to form the entire circumference of the pipe in addition to the laps, regardless of the pipe diameter. Plates that were burned or blistered or not thoroughly and homogeneously rolled were not, under any circumstances, accepted or used.

The wrought-iron pipe was made of sheets rolled into cylindrical sections as specified. The diameter of every alternate section was twice the thickness of the metal larger than that of the other sections, the latter being taken for the nominal diameter in both cases. These sections were riveted together in lengths of about 27 ft., and a cast-iron hub riveted to one end, although two or three 27-ft. sections were occasionally riveted together to form pipes 54 and 81 ft. long.

The spigot ends of the 36-in. pipes were stiffened by bands or rings of semi-elliptic section, riveted to the circumference. The 24-in. pipes were provided with cast-iron spigot pieces about 1 ft. long, riveted to the metal sections. The separate pipes thus formed were connected in the trench by lead joints, as in the case of cast-iron pipes.

The conduit line was completed and put in service in January 1876 and was used continuously until 1934. During this time numerous repairs were made; the records show that most of the leaks were joint leaks which were repaired by calking. Over the nearly 60 years of its life there were few plate leaks and when they did occur they appeared in groups, followed by long sections showing none.

In the section of the line near the lake it was found that a great many of the cast-iron joints had cracked and the leakage was sufficient to cause the abandonment of the section.

During the intervening years, between the construction of Conduit No.

1 and the year 1934, two additional conduit lines were constructed. Conduit No. 2, a 38-in. riveted steel line, was built in 1893, and Conduit No. 3, a 37-in. cast-iron and lock-bar steel line, was built in 1915.

In 1934 a cross-over was built between Conduit No. 3 and Conduit No. 1 at a point about 12 mi. north of the lake where the grades were such that Conduit No. 3 furnished water to Conduit No. 1. The 12 mi. on Conduit No. 1, south of this cross-connection, was abandoned at that time. The abandonment of the upper 12 mi. of Conduit No. 1 reduced the conduit capacity between Hemlock Lake and Rush Reservoir by about 5 mgd., leaving a conduit capacity between these two points of approximately 34 mgd., which was sufficient to take care of the peak loads at that time.

By 1942 the industrial expansion in the city of Rochester, brought on by wartime demands for stepped-up production, had materially increased the demands for water. The problem of supplying war plants operating on a 24-hour basis put a tremendous strain on the facilities for conveying water from the source of supply to the distributing reservoirs located in the city.

The highest monthly average reached in normal times was 32.5 mgd. In 1942 the highest monthly average was 36 mgd., and there was every indication that this amount would be exceeded in the future. This conclusion proved correct, for in 1944 the highest monthly average soared to 39 mgd. in August. On the peak day of this month consumption reached 52 mil.gal. The 1944 average consumption was 35.4 mgd. and because the conduits were not capable of delivering this amount it was necessary to buy water from one of the large private plants and also from a private water company which supplies the suburban area surrounding the city. The cost of this water amounted to $65,485.

In the early months of 1945 the highest monthly average was 36 mgd., equal to the high of 1942, and the average daily consumption, up to October 15, was 36.1 mgd.

These quantities proved to be higher than the amount which the existing conduit lines were capable of delivering. In order to meet an increased demand for water and to eliminate the expense of purchasing water from outside sources, the city determined to investigate the possibility of reclaiming the abandoned portion of Conduit No. 1. Accordingly, a thorough study was made jointly by the water department, the city engineer and Robert E. Horton, Consulting Engineer.

Study and Investigation

A factor to be taken into consideration when the reconditioning project was being considered was the right-of-way. The easements for this conduit, obtained from the property owner in 1873–74, were for the construction of a pipeline, with the stipulation that the city could enter upon the right-of-way for the construction of the conduit and could also enter to maintain and make repairs to same, provided that in making repairs, the city paid for damage to crops, etc. The city did not have the right to construct a new line on this right-of-way, although it might have been construed that it had the right to replace by removing same and replacing in the same location. This, of course, would have involved considerable expense in paying for damages. The other alternative was to acquire a new right-of-way but this also would have been costly and would have re-

quired considerable time to obtain, as it would perhaps have been necessary in some instances to resort to condemnation proceedings.

Preliminary investigation, without putting the line under water pressure, indicated that the wrought-iron plates were generally well preserved, although they had some pit holes and certain of the connecting cast-iron bell joints had cracked through at the hubs. It was realized that the capacity of Conduit No. 1 would go a long way toward providing the additional volume necessary to overcome the deficiency if a sound and economical method could be found for putting the pipe into serviceable condition. The knowledge that a dense cement lining would provide durable protection under which metal would not corrode or deteriorate, as proven by smaller diameter pipelines still in service after more than 70 years, and that it would effectively prevent leakage through such small holes as might subsequently develop from exterior penetration, led to the selection of this material as a protective lining, providing a satisfactory means for its application could be assured.

As a result of the study, it appeared that, after cleaning, a consistent, dense cement mortar lining might be applied throughout the interior of Conduit No. 1 by a mechanically controlled centrifugal machine which would pass through the pipeline from one end to the other. It was found that a centrifugal lining machine had been used successfully heretofore in applying a cement lining to pipes 36 in. in diameter and larger, and so this method of application was adopted, the work was advertised and the contract let.

Preparatory to hydraulic cleaning, two 14-in. pumps were installed at Overflow No. 1 and water was pumped into the line at the rate of 5,600 gpm. At this rate the line should have been filled in eight hours, but when, at the end of seven and one-half hours, it was found that a pipe full of water could not be obtained at the second overflow about 1¾ mi. away and that several major leaks were apparent in the line, pumping was discontinued and it was decided that the pipe would have to be entered and repairs undertaken. While these repairs were in progress a minute inspection of the whole line was made. It was discovered that throughout the entire length distortions occurred in the pipe varying from 1 in. to as much as 7 in. A close survey of the pipe recorded foot by foot revealed that in some places the internal perpendicular measurement of the pipe was a bare 29 to 30 in. and the horizontal measurement 40 to 41 in. This, together with the leaks, caused the greatest difficulty in repairing the line.

Cleaning

While the regular type of hydraulic cleaning machine, which had been contemplated for the removal of the existing rust deposit, tubercles and dirt, is sufficiently elastic to tolerate a distortion of 3 or 4 in. in the internal diameter of a pipe, this excessive degree of out-of-roundness not only would give a poor cleaning job but would, in places, prevent passage of the cleaning machine. The regular cleaner is equipped with flexible spring steel scrapers which will depress at least 2 in., allowing for a total diameter variation of 4 in., but unless the pipe were sufficiently large to permit passage of the rigid scraper mounting, the whole machine would become jammed in the pipe. Even were it possible to jack the pipe out to a size through which the

regular machine might possibly squeeze, the added friction would have necessitated a driving pressure in excess of what Conduit No. 1, in its precarious condition, would be capable of standing. The alternative—cleaning by hand—would not only have been far more expensive, but would have required a great deal of manpower at a time when this commodity was at a premium. Therefore, while repairs were being made on the numerous leaks which the pressure tests revealed, the cleaning company developed a more flexible machine which would meet the demands of the distorted pipe. Additional pressure tests revealed further leaks, most of which were at the cast-iron hubs where either the lead had been forced out of the joint or the bell itself had cracked. In the latter cases the hubs were either reinforced by steel bands or removed and replaced by steel sleeves. Cracks and perforations in the plate were welded and patched. A considerable length of time was required to complete the job of rendering the pipe sufficiently tight to withstand the pressure necessary for driving the cleaning machine. Even then the pipe was not entirely free from leaks, but it was decided that, since the passage of the cleaning machine would probably open up new leaks, only those would be repaired which would materially affect the pressure behind the cleaning machine.

When the new machine was jacked into the pipe at the south end of the line it was sealed in with a blind flange bulkhead. It had progressed only about half its length when the flexible frame upon which the scrapers were mounted buckled. This design was scrapped immediately and another machine, with small, rigid scraper carriages and long steel scraper arms, was substituted. These long arms were held in tension against the walls of the pipe by means of coil springs extending from the carriages to a point a short distance from the base of the scrapers. The void between the blades, which would have permitted too much water to pass the machine, was sealed off with a rubber cuff attached to the piston at the rear of the machine. This cuff reached from the walls of the pipe to the body of the rear piston and provided an additional driving surface for the water behind the machine, and the cleaner, so equipped, proved adequate for the job. The pipe was cut in four places to permit spillage of the water and the accompanying deposits of incrustation and dirt, as well as to provide for the removal of the cleaning machine from the pipe. To insure the best possible results the machine passed three times through each of the four sections between these cuts.

Problems in Lining Leaky, Deflected Pipe

To add to the strength and the tightness of the pipe, as well as to protect the metal from any deterioration from the action of the water within, the city had planned to line the newly cleaned pipe with $\frac{3}{8}$-in. mortar lining. This lining was to be applied by centrifugal machine in an even dense coating and was to be troweled to a smooth finish. Here again the deflections in the pipe presented a major problem. One has only to glance at the construction and functional parts of a centrifugal lining machine to appreciate the difficulties. The machine consists of a hopper into which the mortar is fed and through which runs a long tapering worm. This worm serves to force the mortar into a narrow tube, vented near its ex-

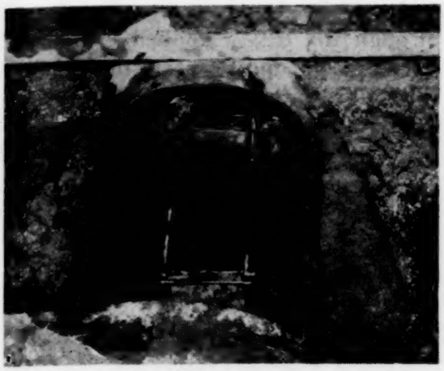

FIG. 1. Mortar Buggy Inside of Pipe

tremity with a series of parallel slots which runs lengthwise to the neck. The mortar fed into the hopper is forced by the worm to the far end of the neck, where it finds exit through the vents. The distributing head, a device revolving at high speed around these vents, picks up the extruding mortar and propels it in a fine spray onto the walls of the pipe. The somewhat granular surface of this centrifugally-cast cement mortar lining is then smoothed by trowels which operate a short distance behind the revolving head. These trowels exert a slight pressure against the mortar surface and are capable of sufficient flexibility to take care of the variations of pipe diameter normally encountered. However, as previously observed, the deflections in Conduit No. 1 were exceptionally severe and greatly in excess of the variations customarily encountered in steel water mains. Since these irregularities in the diameter of the pipe occurred at short intervals without cessation throughout the whole length of the main, an almost impossible troweling problem was presented in never-ending time-consuming trowel adjustments. It was therefore considered advisable to abandon troweling the lining entirely. This decision was also influenced by the fact that the 36-in. wrought-iron main delivered its supply into a 24-in. line of equal age. This 24-in. line ultimately delivers the water at Rush Reservoir and controls the volume of water carried. A small loss in the coefficient of discharge of the 36-in. pipe would not materially affect the carrying capacity of the 24-in. line. Results of flow tests showed a Hazen-Williams coefficient of 90 on the 24-in. line and 100 on the 36-in. line after reconditioning.

Centrifugal Mortar Lining

While the city maintenance crew located and repaired the leaks still existing in the line after the cleaning operation had been completed, the contractor set up the lining equipment and started to dry, screen, bag and weigh the sand to be used in the mortar mix.

Because cement lining has been described in considerable detail in previous issues of this JOURNAL, particularly in that of September 1936 (**28**: 1348–1371), an extensive discussion seems unwarranted here.

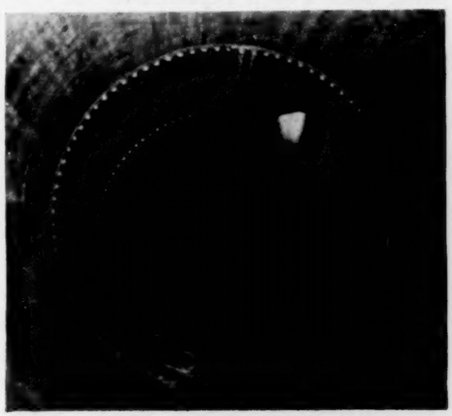

FIG. 2. Interior of Pipe After Cleaning

Briefly, the lining machine, powered by an electric motor, travels through the pipe centrifugally spraying the cement under high pressure uniformly upon the pipe walls as it progresses. Rotating adjustable trowels follow immediately behind, effectively smoothing the surface so as to reduce the friction of the flowing water to a minimum.

The cement mortar is mixed above ground and is dropped through convenient pipe openings into rubber-tired buggies, by which it is transported in the pipeline to the centrifugal liner.

In a perfectly round 36-in. pipe the work is difficult enough; in a distorted pipe the hardship is greatly increased. Work within a 36-in. pipe calls for considerable stamina and agility and it is difficult to find labor physically capable of sustained effort in such cramped quarters.

Plastering and Finishing

Before the pipe was lined all the joint spaces were partially filled with mortar so that the interior of the pipe after passage of the lining machine would present as nearly as possible a smooth uninterrupted bore. While this was being done a crew repaired all the visible leaks, keeping a couple of days ahead of the work of the lining crew. It was found, however, that when the lining machine passed through the pipe other leaks broke out which were not discernible unless the line was under strain. The two rear wheels of the machine ride a few inches up on the side walls of the pipe and the weight of the machine fully charged with mortar was sufficient to spread the metal enough so that the ground water would infiltrate, spurting up through previously undetected pin-hole leaks. These miniature geysers would erupt directly under the head and play in a fine stream through the newly applied coating of mortar. In most cases these leaks would heal themselves when the full weight of the machine was removed from the plate in which the leak had sprung, and a small dab of mortar applied the following day to the point where the mortar had been washed away was sufficient to effect complete repair. In more stubborn cases, however, where the seepage of water continued, it was necessary the next day to stop the leaks with a mix of neat cement and a solution which caused almost instantaneous setting. This in turn was covered with a coating of mortar to a point flush with the lining.

All the access holes in the line were closed as rapidly as possible with $\frac{1}{4}$-in. plates which were welded into place. The area beneath each plate was plastered with mortar by hand and any cracks which might have occurred in the surrounding mortar due to the intense heat of the welding were also sealed and coated with mortar. Water was introduced into the line as rapidly as possible to cure the cement lining. Since there were many hills over which this conduit ran, it was easy to control the flow. After the lining and the plastering had been completed over the brow of a hill it was possible to allow the water to fill the pipe gradually to a point just short of the high spot, thus providing an ideal curing medium for the newly applied mortar lining.

Work on the lining of the main was started on September 12 and was completed on November 22, 1944. The general contractor for the project was the Centriline Corporation of New York City. This company sublet the hydraulic cleaning of the line to the National Water Main Cleaning Company and sublet the complete work of

lining the main to the Lock Joint Pipe Company of East Orange, N.J.

Results

The city paid to the Centriline Company for cleaning and lining a total of $145,973.32. The leaks at the cast-iron joints where the lead had pushed out or the hubs had cracked had to be dug up and repaired and this work was done by city forces and added to the cost of reconditioning. The additional sum spent by the city amounted to $28,220, making a total cost of $174,193.32 for 38,131 ft., or $4.57 per ft. After reconditioning, the 36-in. line tested to a coefficient $C = 100$. This is equivalent to a new 33-in. line having a coefficient $C = 130$. The cost of laying a new 33-in. line at that time would have been at least three times the total cost of reconditioning the old line and the time required would have been much longer. Because of the use of the reconditioned conduit it has not been necessary to purchase water from outside sources so that the city has profited by saving both time and money.

Practical Problems Involved in Employing Returned Servicemen

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WORLD War II has made many changes in the American way of life, some of which are for the better. In spite of rationing, for example, we are better fed, as a nation, than we have been at any previous time in our history. Our diets have been balanced, which is more than can be said for some of our thinking. One thing World War II hasn't changed, though, is that most cherished heritage of ours of being able to surround anything new or different with an aura of terms and phrases, making it so clouded that it is difficult to recognize. And, of course, being in America, whatever we do has to be the biggest and best; so we have done this one up in first-class shape. Sociologists and psychologists, with all due respect, have been having a field day expounding profound theories on the serviceman's possible psychoses, his emotional framework and his readjustment problems.

It is my opinion, and I am not a veteran, that in surrounding this subject of returning servicemen with a multitude of descriptions, definitions, terms and phrases, we have almost lost sight of the original problems by superimposing a problem of monumental proportions upon them. It is hoped that this paper will assist in eliminating some of the fog that beclouds the real problems.

It is admitted that some of the returning servicemen will have problems, problems that will be real and problems that will require intelligent action if they are to be solved; but, at the present time, *we are the biggest problem facing the returning serviceman!*

The war had hardly begun when we began to worry about the boys coming back; and the more we thought of their returning, the more we surrounded it with possibilities, until we have conjured up in our own minds a host of *problems* with which every veteran *must* be faced. The sooner we can abolish such a figment of our imagination, the better off we, and the veterans, will be. As an example, most of us upon hearing the term *disabled veteran* immediately picture a man with an arm or a leg missing. Thus, when we hear of so many hundreds of thousands being discharged for disability, most of us begin thinking in terms of so many hundreds of thousands of jobs for legless or armless men. Actually, what is the employment problem involved for a serviceman who has lost a leg or an arm? As a result of this war there are going to be approximately 30,000 amputees. Our postwar economy, according to the planners, will provide somewhere between fifty and sixty-five million jobs—Henry Wallace says sixty million, the Committee

for Economic Development says fifty-five million. Discounting both and taking fifty million jobs, this means that, in order for industry to absorb these 30,000 amputees, only 0.6 per cent of the jobs will have to be tailored to fit them—yet many of them will not require tailoring at all because they are jobs not requiring the use of the extremities. Furthermore, the intelligent resourcefulness of many of these disabled veterans will generally excel that of their more normal looking brothers.

Before being accused of a callousness that I do not possess, let me hasten to assure you that the problems of these 30,000 men, along with the problems of the other physically or mentally disabled, are real and must receive our serious consideration. It is not my intention to belittle the necessity of providing opportunities for them, nor to imply that they should receive any less thought and attention. The point I am making is that all of these men together are still the exception rather than the rule. About 90 per cent of those who are, or will be, veterans of this war are just folks like everyone else, men who want to be treated like everyone else and who ask for no special favors or privileges. Because some veterans will have difficulties, it does not follow that all veterans will have problems, other than the problems which face everyone of us from day to day.

If this fact can be impressed on the minds of the American public, we shall have solved the biggest problem facing the veteran today. If we do not soon recognize it, we are going to create problems for which there will be no satisfactory solution.

From the information available to me, it is my belief that the number of veterans who will be in need of special consideration of one sort or another, i.e., veterans who will have problems, will approximate 10 per cent of all veterans. The amputees previously referred to will constitute approximately 2 per cent of the disabled veterans, or some 0.2 per cent of all veterans.

No attempt will be made to present any detailed discussion of the legal problems involved in the re-employment of veterans because the limits of this paper would prohibit any comprehensive discussion. A wealth of data by competent authorities that deal with the legal aspects of veterans' re-employment is available elsewhere.

In substance, the Selective Training and Service Act of 1940, after setting forth certain provisions for the serviceman's re-employment relating to his ability to perform the duties of his former position and to the necessity of his making application within 90 days, states that the federal government *shall* restore such a person to his position or to a position of like seniority, status and pay; and that a private employer shall do likewise unless the private employer's circumstances have so changed as to make it impossible or unreasonable for him to do so. Since many of the water utilities are publicly owned, it is well to note that the act states, "If such position was in the employ of any state or political subdivision thereof, it is hereby declared to be the sense of the Congress that such person should be restored to such position or to a position of like seniority, status and pay."

Complicating factors have arisen and will continue to arise for those organizations that are publicly owned, since individual charters may prohibit the accomplishment of what might otherwise be considered desirable for a par-

ticular veteran, and what would be done for him if he were in private industry. If such is the case, steps should be taken to amend your charter, or rules, so that your treatment of veterans is in accord with that of industry as a whole. Are you able, under your Civil Service Rules, for example, to transfer a former meter reader who has lost a leg to some other position of equivalent status, where (and this is most important to his welfare) he can make a real contribution in your operations? Again, do your rules prohibit the granting of an annual leave to your returned veteran—a practice being widely adopted by private industry?

At least in so far as the re-employment of veterans is concerned, it could be said that the private employer is fortunate in that the government will tell him what he can and what he cannot do. Not so, to my knowledge, the public employer. It is questionable whether the government can, or will, prosecute a municipal corporation under this act. Consequently, the policies of the public employer will be determined in large measure by public opinion and by a sense of the moral obligations involved. Veterans returning to your employ may create situations that will prove embarrassing if your policies are not pretty well established and in conformity with prevailing practices. These men are not going to be satisfied with an explanation stating that the reason a given thing cannot be done for them, although private industry may be doing it, is that you have a rule against it. They are going to reason that it didn't take very long for the government to adopt laws to get them into the services; therefore, it should not be so difficult to change one of your rules in order that you can comply with what others are doing.

Clear-cut policies, in keeping with prevailing practices, and adopted in advance, will eliminate what might otherwise become problems connected with employing returned servicemen.

Pensions and Leaves

Does your returned serviceman obtain credit in your pension plan? And if so, does he have to make contributions for the period of his absence? Many private employers are granting credit and are also paying the veteran's contributions. Many public employers are making it optional with the veteran and are depositing matching contributions, where this type of plan is in effect, if the veteran does elect to obtain credit for the period of his leave.

Is your veteran entitled to an annual leave upon his return? Many private employers grant at least one annual leave during the year of his return, while some are granting the accumulation of his annual leaves for the period of his absence.

How do you determine the returned serviceman's accumulated sick leave? Some employers grant sick leave during the period of military leave and then accumulate it on the assumption that none was used, while others take the veteran's sick leave standing at the commencement of his military leave, carry it forward to the date of his return and continue from there.

These are typical examples of the questions for which policies should have been adopted. The necessity for an immediate review of the policies of your organization, if this has not already been done, cannot be over-emphasized.

It is not enough, however, to determine policies. The most liberal policy in the world isn't worth the paper it is written on if it isn't prop-

erly understood and soundly administered. First, one person in your organization, or in each of your major establishments, should be charged with the re-employment of your veteran and of acquainting him with your policies concerning him. Preferably this person should be a veteran himself—one who knows the services. If he is, he will know enough to keep to a minimum the number of questionnaires and papers that require signatures and he will avoid red tape at any cost. He knows what these veterans have been through and what they will have to go through if required to deal with any of the governmental agencies regarding insurance, pensions, G.I. Loans, etc. It is a sad commentary on our way of doing things, but the services for veterans have become so complex that many communities have found it necessary to set up Veterans' Service Councils for the purpose of co-ordinating the services of existing agencies to the veterans and of operating "information centers" so that the veterans needing assistance can be referred to the agency best able to assist them. Incidentally, your personnel officer, or whoever else is charged with the reception of your veterans, would do well to acquaint himself with the facilities that are available for veterans in your community.

Reinstatement

Policies should be formulated, but they should not be formalized. In reinstating the veteran, don't regiment him. He's had enough of that. While policies should be rigid, their means of application should be flexible. The object is to get your servicemen back at work—the procedure whereby you accomplish that should be fitted to the needs of the individual.

The success of your reinstatement plans for your veterans will depend in large measure upon the simplicity of detail and the attitude displayed. Just as with new employees the first impressions may be the ones that last. Your employee relations for many years into the future will benefit if the veterans' receptions are properly conducted.

Undoubtedly some contact has been maintained with each of your employees while they were in service. In the author's organization this has been accomplished by sending them copies of our house organ each month and by letters written to them by the person or persons in the organization who appeared most logical to do so, whether it was a personal friend, a fellow worker or a supervisor. The letter writing was co-ordinated by a member of the house organ staff who gathered the material of general interest received in the replies, summarized it and published it in a column designed for that purpose. But, whatever means you used, don't start now to bombard those still in service with questions about when they will be discharged, whether they plan to come back to work for you, or whether they expect their old job back, or something else. The temptation to do so will be strong. You might set up your organization one way if you knew that Smith was coming back or you might do it another if you knew Jones planned to go into business for himself. They are just as anxious to get out and decide what they are going to do as you probably are to have them. Questioning them now will only serve to increase that anxiety. They've sweated it out for you more than once, now you sweat this one out.

Besides, the making of decisions is going to be a real problem for some of them. While relatively few of our returning veterans will have been in service long enough to have become so regimented that they will have difficulty in making decisions—for the most part, decisions have been made for them while they were in service—nevertheless there will be some who will be affected. This inability will be very real and will require patience on your part if the veteran so affected is to resume his proper place with you. These men must be allowed more time to adjust themselves—don't load them down at the beginning.

Perhaps a word which will more adequately describe a large majority of the troubles that are besetting, and will beset, the 10 per cent of the veterans under consideration, the veterans with so-called problems, is "instability." It would include any uncertainties regarding vocation, problems arising out of environmental or family relationships, and any emotional disturbances resulting from their experiences, or from being thrust back into civilian life.

The person in your organization assigned to returning your veteran to his job, if he has had any experience in interviewing, will normally be able to bring out most of the instabilities which may be confusing the serviceman. However, there will be many of these instabilities that will not develop until the veteran is back on the job. Consequently, there is going to be a need for close co-ordination between your foremen and your placement officer if these uncertainties are to be caught as they develop. Follow-up interviews should be held, both with the veteran and with his foreman, and they should be conducted at times and in such a manner that the veteran is not made to feel that he is under observation nor that there is any anxiety over his ability to do the job.

Medical Examinations

At the initial interview, the more obvious disabilities, either physical or mental, will be readily apparent, but even prior to the war, medical examinations were required by most industries to bring out the physical and mental impairments that couldn't be discovered by the layman. If you have a program of periodic medical examinations the matter of having your returning veteran examined before replacement will be relatively simple. If you do not have such a program, a great deal of tact will be necessary in order to avoid resentment by the veteran should you require him to submit to a medical examination prior to reinstatement. He should be made to feel that such an examination is primarily for his welfare and that it is not going to be used as an excuse to deprive him of his place in your organization unless such deprivation is essential to his well being, in which event it will be used to place him on a job better suited to his capabilities.

The code numbers on the discharge certificate, by reference to material that is readily available to you, will tell you whether or not your veteran received a medical discharge. It will not tell you if the discharge was for a physical or a mental disability nor what the specific nature of the disability was. This information is confidential, although it may be released to the veteran's employer if the veteran requests in writing that it be done.

Of all the reasons for discharges, perhaps the haziest and at the same time the least understood by the layman is the psychiatric discharge. Prior

to the termination of hostilities, approximately 45 per cent of those discharged from service up to that time were for psychiatric disability. This percentage has reduced considerably with the increased number of discharges resulting from the demobilization of our Army and Navy. Nonetheless, the number discharged for psychiatric reasons is significant and will continue to be so for some years because of the very nature of the illnesses involved. The re-employment of most of these men, however, does not present an insurmountable obstacle. Incidentally, in September 1945, there were 319,000 veterans of World War II residing in California and there will be well over 1,000,000 after demobilization.

All of us are keenly aware of the load we had to carry, particularly on the West Coast, because of the increased use of water resulting from the war effort. We met this load by taking on new workers, both as additional help and as replacements. Many of them had been rejected in the draft for the same reasons that some veterans were discharged under the heading of psychoneurotic disability. In fact, many of them were worse than the veterans being discharged; if they weren't, how is it that the Army and the Navy were able to screen them out before they ever got started? Yet, they performed their jobs capably for the most part, and many of them are still with you. The only reason you didn't know *who* they were was because they didn't have a piece of paper saying so.

The nature of psychiatric disabilities is vague to the layman. Too much strain is the main cause of the most of these affections. While these mental strains occur more frequently in war, they are not necessarily peculiar to it. Industry and government have long recognized this by the granting of annual vacations, particularly to those engaged in occupations requiring considerable mental activity. All of these strains are grouped under the heading of *psychoneurotic disability* just as all wounds and physical illnesses are classed as *physical disability*.

Generally, three large categories of mental affections are recognized in medical circles:

1. *Psychosis* (commonly known as insanity) is a mental disorder of a severe nature in which there is a complete disintegration of the normal personality and in which the individual is completely out of touch with reality in one or more ways. The person who believes himself to be Napoleon is an example of the type most easily recognized. The recognition of others is more difficult. Fortunately, the total number in this group is comparatively small. Generally they will not be employable, although a few veterans falling within this category may find their ways back to your organizations in spite of the most careful screening. They comprise cases that should be dealt with only by trained technicians.

2. Cases resulting from damage to the brain structures, such as wounds, syphilis, epilepsy, etc. Although there has been a great deal of advancement in making such people employable the number who can be usefully employed with safety to themselves and to others is relatively small.

3. *Psychoneurosis,* a disturbance brought on by mental and emotional factors which prevents one from leading a normal life. Typical examples of these are the individuals who complain of aches and pains, yet upon examination are found to be organically sound. Although their disturbances are due to

emotional problems they are nonetheless real.

Another group of psychoneurotics are those who are suffering from anxiety neurosis. It is by far the largest group and its members are characterized by disabling anxiety, uncertainty and insecurity.

Finally there are the psychoneurotics who are suffering from fatigue—"battle fatigue" as some have called one phase of it. They are exhausted, always tired. When this fatigue is severe enough to be disabling it is called "neuresthenia."

Contrary to popular belief, the strong as well as the weak suffer from such mental disturbances. They do not occur only to weaklings.

Practically all of the veterans in this latter category can be returned to normal living when subjected to proper treatment. By treatment is meant the care given by competent individuals. Your personnel officer should be familiar with the sources in your community from which competent assistance can be obtained in helping these men. This cannot be over-emphasized because there will be many cases in which the psychoneurosis will not become apparent until after the veteran has been discharged and is back on the job for some time.

Your greatest contribution in the solution of the instabilities of these men is the establishment of a personalized relationship between them and management. If a digression is permitted, the establishment of a personalized relationship between management and all of its employees would go a long way toward solving the problems that confront us in the field of industrial relations.

The person charged with inducting returned servicemen should be one to whom they can go with their problems, whether they be social, economic or personal. Again, he should follow up their return to work by interviews with them and with their foremen. If he is in anyway skilled in the art of interviewing he can soon draw out any problems that may exist. Many of these instabilities can be remedied by a sympathetic listener. Perplexing problems are often straightened out by merely telling them to someone else. Needless to state, this interviewing must be done adroitly and sincerely.

The following points, borrowed from a summarization by the Surgeon General of the Army, regarding attitudes toward the psychoneurotic veteran can well be followed:

1. Do not heap too much responsibility on them. Work in gradually, as they grow more accustomed to civilian life and their work. Remember that it may take as long as a year before the discharged soldier has recovered from what he has gone through.

2. Do not ask too many personal questions or give too much advice. (This is sound reasoning anytime.)

3. Be casual and realistic with them, not overcheering or oversympathetic.

4. Treat them as normal people, which it is assumed they will become if they are properly placed and rehabilitated.

5. Always remember you are dealing with an individual, not a handicap.

Physical disabilities are not as confusing to the non-medical man. The physically disabled veteran will require special understanding and careful handling, done in such a manner that there is no hint to him that he is a special or problem case. He will resent being made to feel that he is the recipient of "charitable" employment.

Providing an opportunity for your returned serviceman, who is physically handicapped, to take care of himself affords an unexcelled public relations opportunity. Providing a place where your returned serviceman who is physically handicapped will be taken care of will yield an opportunity for questionable public relations, because consumer groups, Chambers of Commerce, etc., may become too aware of it. Even they may openly commend you for it, for they must think of public relations also, but behind your back they may question just how enlightened you really are.

Peculiarly enough, the advancements made by medicine since World War I have made this a relatively greater problem. In the last war the soldier died of his wounds on the battlefield; in this war he recovers to accept a useful place in our economy, assuming that industry, and we as a part of industry, do our part in providing those places. It presents a great challenge and yet it is one that can be met with just a little preparation on our part.

The building of airplanes and the construction of ships have demonstrated what can be done by the use of the physically handicapped. This great production would not have been possible were it not for the employment of handicapped individuals. Something in favor of the employment of those who are physically handicapped that is not generally understood is that, *when properly placed,* their performance is better than the average for other groups; they have fewer absences, fewer accidents, fewer terminations of employment, voluntary or otherwise; and by comparison they produce more per man.

In the rehabilitation of physically disabled veterans, our government, through the Army and Navy medical services, is indoctrinating these men, not with the idea that they will be taken care of, but with the idea that they will be put into shape to take care of themselves. If we are not to nullify this whole concept of restoring returned servicemen to their rightful places in our economy and our society, it is up to us to provide the opportunities for handicapped veterans.

A brief review of the positions that make up your organization will quickly reveal the opportunities available for employing the physically disabled. If you have a job analysis and job classification program in operation, this review will be greatly simplified. In essence, each job should be broken down into its component parts, itemizing the physical characteristics required and the working conditions involved. Those jobs that cannot be performed by anyone with a major handicap will be readily apparent and they can be eliminated from further consideration. The remaining jobs should then be appraised in the light of the degree of physical effort needed and a tabulation made for each.

The limits of this paper prevent the presentation of a job analysis program in any detail. Those that are interested can obtain sample forms, instructions, etc., from any of a number of accepted books on the subject, or from organizations that have job analyses programs in operation. The U.S. Civil Service Commission has a classification code for physical activities that can be used to analyze any job.

In order to make effective use of the job analysis data in the reinstatement of your handicapped veterans, it is necessary to have reliable information on their handicaps, information that can only be furnished by a competent

doctor. Such information should be provided in a manner that it can readily be evaluated in the light of the job analysis by whomever is placing your returned veterans. Several of the national industrial concerns, and probably many of the local industries, make use of forms in their systems which can be adapted to our industry. The Permanente Foundation, in conjunction with the War Manpower Commission, prepared a comprehensive job analysis, medical examination and placement plan for the utilization of handicapped persons in the shipyards. It was their intention to expand this to include jobs in other industries. Little, if any, revision would be needed to adapt it to the water utility industry, since many of the jobs, such as draftsman, watchman, welder, clerk, machinist, pipe fitter, etc., are practically identical in both.

First, last and always, it should be rememebered that in dealing with veterans we are dealing with individuals. As individuals, what would be proper for one may be improper for another. If we can remember this in our dealings with our returned veterans it will be difficult, at least insofar as we and they are concerned, to determine what these veterans' problems are that everyone seems to be talking about.

Bill Mauldin, in his book *Up Front*, Henry Holt and Co., New York, has something which sums up not only the problems of employing returned servicemen but all of their problems. Although he writes of combat veterans, his words are applicable to all, since the combat veteran is supposed to present the worst problems.

In taking a dig at our social service preoccupation with the *returned veteran problem* he writes, "This feeling has been so strong in some places that veteran combat men are looked at askance by worried and peaceable citizens." But, says Mauldin, "there are so few men in the Army who have really gone through hell that when they return they will be soaked up and absorbed by their various communities and they couldn't be problems if they wanted to."

"They simply need bosses who will give them a little time to adjust their minds and their hands, and women who are faithful to them, and friends and families who stay by them until they are the same guys who left years ago. No set of laws or Bill of Rights for returning veterans of combat can do the job. Only their own people can do it."

I believe we are their people.

Digest of the British Water Act of 1945

By Harry B. Shaw

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A contribution to the Journal

THE British Water Act of 1945 is arranged in five sections as follows:

I. Central and Local Planning

II. Local Organization of Water Supplies

III. Conservation and Protection of Water Resources

IV. Powers and Duties of Local Authorities and Water Undertakers (a public water department or a private water company)

V. General

At the end of the act are five schedules in which are outlined the details of the procedures to be followed when operating under the act, amendments to the Public Health Act of 1936 necessitated by the passing of the Water Act of 1945 and the repeal of other legislation included in the Water Act of 1945.

Part I—Central and Local Planning

The Minister of Health (hereinafter called the Minister) is charged with the duty of promoting the conservation and proper use of water resources, providing for water supplies in England and Wales and of securing the effective execution by water undertakers of a national water policy.

The Minister is directed to appoint a Central Advisory Water Committee which shall advise him or any other minister on matters connected with the use and conservation of water resources and to which he or any other minister concerned may refer for an opinion any question concerning acts or proposed amendments to acts relating to the use and conservation of water resources or provision for water supplies.

Should the Minister decide that the providing of water supplies or the conservation of water resources in any area in England or Wales would thus be more effectively secured, he may appoint a Joint Advisory Water Committee consisting of a chairman appointed by the Minister, representatives of the water undertakers operating in the area and the local authorities. The expenses of the Committee are paid by the local governments.

The duties of such Joint Advisory Water Committee may include:

a. A survey of the water consumption and demand and of the water resources of the area.

b. Preparing an estimate of future water requirements.

c. Preparing proposals for meeting the existing and future requirements.

d. Advising the statutory water undertakers and local authorities as to the preparation of water supply schemes.

e. Furnishing the Minister, water undertakers and local authorities with information relating to water supply and resources for the area.

The Minister may require the Joint Committee to report upon (a), (b) and (c) from time to time. The Com-

mittee is empowered to require the water undertakers and local authorities to furnish such information relating to their water works unless the requirement is impracticable or would result in undue expense.

The Minister may require any local authority or statutory water undertaker essentially to carry out the duties of the Joint Advisory Water Committee outlined above except as under (d).

The Minister may make regulations requiring all persons abstracting water from any source to furnish records as to the quality and quantity of water and matters relating to the source, except that such regulations shall not apply to a case where water is abstracted by an individual for the domestic purposes of his household only, or the regulations may be waived in any case where the Minister deems them impracticable or unduly expensive.

Part II—Local Organization of Water Supplies

When any joint water board and local authority are in dispute with respect to the furnishing of water in bulk by the board to the authority, either party may refer the dispute to the Minister, whose decision shall be binding on the disputants.

Upon the application of the water undertakers concerned the Minister may authorize: (1) the joint furnishing of a supply of water, (2) the formation of a joint board exercising all or any of the functions of the undertakers relating to water supply, (3) the amalgamation of the undertakings of the water undertakers where the latter are not a local authority, and (4) the transfer of all or part of the undertakings of one water undertaker to another. In the latter case, if it appears to the Minister to be expedient for securing a more efficient supply of water to make provision for certain matters, he may by compulsory order provide for such matters.

The Minister may, upon the application of any statutory water undertakers supplying water under a local enactment, vary the limits of their supplies by order. When it appears expedient the Minister may issue such an order compulsorily.

The Minister may authorize water undertakers, upon application, to furnish area outside their territory with water, provided the undertakers in whose territory the area in question is located agree or that the serving of such area will not adversely affect the supply of the serving undertakers' statutory territory. However, the undertakers of whose territory the area is a part may subsequently give three months' notice to the supplying undertakers that they intend to serve the area in question. Upon the expiration of said notice the undertakers receiving the Minister's order shall cease to have any rights or duties in respect to supplying the outside area. Such of the pipes, plant and apparatus installed by the undertakers receiving the Minister's order shall be left in place as are required by the undertakers giving notice, for which the latter shall pay the former an agreed price or price arbitrated by an appointee of the Minister.

Statutory water undertakers may enter into an agreement to secure a supply of water in bulk, with the provisions that: (a) the approval of the Minister must be received and that where the supply is furnished by statutory water undertakers, he shall withhold his approval if the furnishing of said supply would interfere with the supply for any purpose within their territory; and (b) where the supply is

to be given to a local authority and the area to be supplied is within the territory of another statutory water undertaker the agreement shall require the consent of such other undertakers, which, however, may not be unreasonably withheld.

Where the carrying out of the above provisions of the act would conflict with existing statutory requirements, the approval of the Minister, if the other governmental agencies affected object, does not have effect until confirmed by Parliament.

When the Minister deems it expedient that any statutory undertaker should supply other statutory undertakers, and the latter take a supply of water in bulk, and he is satisfied that such supply cannot be secured by agreement, he may order the respective undertakers to give and take such supply under such terms and conditions and for such period as he may prescribe.

Should a complaint be made to the Minister that any local authority or joint water board constituted under the Public Health Act or any statutory water undertaker supplying water under local enactment has failed to carry out its prescribed duties, or should he be of the opinion that an investigation should be made as to whether such authority has failed to carry out its duties, he may cause local inquiry to be held into the matter.

Should the inquiry disclose failure on the part of the local authority, the Minister may order the authority to remedy the default in discharging its functions. Upon failure to remedy such default within the prescribed time the Minister may transfer to himself the functions of the body in default. Where the defaulting body is the council of a county, district or joint water board, the Minister may transfer the functions to the county council where the functions are mainly exercisable. The expenses incurred either by the Minister or county council are charged to and/or made the obligations of the defaulting body. The Minister's order may provide for the transfer to the Minister or county council of property or liabilities of the defaulting body.

Part III—Conservation and Protection of Water Resources

Whenever the Minister decides that special measures are necessary for the conservation of water in an area he may make an order defining the area.

In such an area no well or other work can be constructed for the purpose of extracting water from the ground and no existing well or work can be extended for the purpose of extracting additional water from the ground unless a license has been obtained from the Minister. Exceptions are made where the abstracted water is to be used only for domestic purposes, or where the construction is authorized by an enactment. Applicants who have been refused licenses are entitled to a hearing by a person appointed by the Minister.

Persons desiring to abstract minerals from the ground in such defined areas shall notify the Minister to that effect, and shall take such measures for conserving water as may be prescribed by the Minister. Upon request such persons also shall receive a hearing upon any requirements prescribed by the Minister.

Wastage of water from wells is prohibited. A fine of not over £10 for each offense of wasting water is provided and, in addition, the well or other work may be sealed by court order, or the court may make such other order as is necessary to prevent the waste of wa-

ter. Should the offender fail to comply with the court order, the court may, upon application, order the local authority or any statutory water undertaker likely to be affected by the waste to execute the order, and any expenses so incurred may be recovered as a civil debt from the person convicted.

Statutory water undertakers may enter into agreements with land-owners, tenants, or a local authority for either party, to build and maintain works necessary for draining land or for more effectually collecting, conveying or preserving the purity of water which the undertakers are authorized to take. Where the works involved result in the discharge of water, except through public sewers, into a watercourse which is within a catchment area or fishery district or which is subject to the jurisdiction of a navigation authority, the undertaker must first consult the concerned authority. The construction and maintenance of sewage works is considered to come within the scope of such agreement as above outlined.

Should they be of the opinion that a water shortage is threatened, water undertakers may prohibit or restrict for such period as they think necessary the use of water for watering private gardens or washing private motor cars, or water drawn through hose pipes. Notice of such prohibition or restriction, violations of the same and adjustment of the water undertakers' charges on account thereof are provided for.

Statutory water undertakers may make by-laws for preventing waste, undue consumption or misuse of water supplied by them. (This amounts to the control of plumbing.) The undertakers can correct any contravention of of such by-laws and collect the cost thereof from the offending person as a civil debt. The offender can also be fined upon conviction.

Statutory water undertakers may by by-laws define any area in which water owned by them needs to be protected from pollution and may prohibit or regulate the doing within that area of any specified act. The undertakers may by notice require an owner or occupier of property within the designated area to execute and keep in good repair such works as they consider necessary to prevent the pollution of their water. Upon the failure of the owner to comply with such notice he shall be liable to summary conviction. Should the owner, however, consider the requirements of the notice unreasonable he may within 28 days appeal to the Minister, who may determine the appeal himself or refer it to an arbitrator. The undertakers shall compensate the owner within the defined area for any curtailment of his legal rights or for expenses incurred in complying with such by-laws. Differences as to the amount of compensation are referred to an arbitrator appointed by the Minister. If the owner fails to comply with the undertakers' requirements and if he has not appealed to, or has failed in his appeal to, the Minister, the undertakers may execute and keep in good repair the required protective works.

Such procedures as outlined in the preceding paragraph can be taken by two or more undertakers jointly.

The Minister shall be the confirming authority as regards the above mentioned by-laws.

Undertakers making by-laws are charged with their enforcement.

Contravention of by-laws is subject to a fine of not over £25 for each offense and £5 for each day the offense continues after conviction.

When any undertaker considers one

of its by-laws unreasonable in a particular case he may appeal to the Minister to relax or dispense with the requirements thereof, provided he gives notice of the proposed relaxation in such manner as the Minister directs.

Authorized representatives of water undertakers are given the right of entry to premises, within reasonable hours, upon presentation of their authority, for the purpose of ascertaining any contravention or of carrying out the purpose of the by-laws made by the undertakers.

By-laws made under the sections of this act shall cease to have effect after ten years and similar by-laws made under any other enactment shall cease to have effect after five years. However, the Minister is empowered to extend the period during which the by-laws referred to are to remain in force.

The Minister may by notice require any statutory water undertaker to make, revoke and remake such by-laws as are relative to the preceding matters and, upon the undertaker's failure to do so within three months, may make, revoke and remake them himself, in which case they shall have the same force and effect as if the by-laws had been made by the undertaker and approved by the Minister.

Any person guilty of any act or neglect whereby a spring, well or adit used or likely to be used for human consumption, domestic purposes or in manufacturing food or drink for human consumption, is polluted or likely to be polluted is guilty of an offense against the act. Any authorized representative of the water undertaker within whose limits of supply the spring, etc., is located is given the right of entry on premises to ascertain whether the act has been contravened with respect to said well, etc.

Cultivation of land and oiling of roads are, however, not restricted by the act.

Water undertakers may acquire land for the purpose of protecting against the pollution of water which the undertakers are authorized to take and they may construct works for disposing of foul water arising from or flowing upon that land or otherwise preventing the water belonging to the undertakers from becoming polluted.

Part IV—Powers and Duties of Local Authorities and Water Undertakers

Construction of Works and Acquisition of Lands and Water Rights

The Minister may authorize, upon their application, any persons to supply water to any area and to borrow money and construct works for this purpose, provided the local authority or any statutory undertaker supplying water under local enactment wherein the area lies consents. Such consent may not be unreasonably withheld, however, which fact shall be determined by the Minister.

With the consent of the Minister statutory water undertakers may acquire land by purchase, lease or exchange for the purposes of their undertakings. This includes land for homes and recreation grounds for their employees. Land may be acquired compulsorily, if such an order is approved by the Minister, for any of the purposes of the water undertakings except for homes, etc., for the undertakers' employees.

Land may not be compulsorily acquired, however, if it is the site of an archaeological monument or the property of a local authority or if it has been acquired for the purposes of constructing under an enactment any rail-

way, canal, inland navigation, dock, harbor, tramway, gas, electric or other public undertaking.

Land belonging to the National Trust * inalienable or being part of a common or allotment may be acquired under a compulsory order only if confirmed by Parliament, unless at least an equal area is given in exchange and certified by the Minister of Town and Country Planning or the Minister of Agriculture, respectively, as the case may be, to be equally advantageous to the public or persons having commonable or other rights.

With the consent of the Minister statutory water undertakers may dispose of land held by them, making such reservations with respect to water rights and the use or pollution of water as they think fit.

Statutory water undertakers may acquire water rights either by agreement or compulsorily with the approval of the Minister. Where the impounding of a stream is involved, however, the Minister shall not approve any agreement unless it requires that an adequate quantity of compensation water is provided. Any compulsory order shall prescribe the amount of compensation water to be provided. Should any catchment or fishery board or navigation authority object and not withdraw such objection to such an agreement the order shall not have effect until approved by Parliament.

Duty to Supply Water for Non-Domestic Purposes

Water undertakers, supplying water otherwise than in bulk, shall upon request furnish water for other than domestic purposes upon reasonable terms and conditions, provided that such water supply does not have to be furnished if by doing so the ability of the water undertaker to meet present and future water supply requirements without incurring unreasonable expenditures would be endangered. The Minister may determine questions concerning such matters or refer them to an arbitrator. Failure of the undertakers to furnish or maintain a water supply under this section subjects them to the same penalties as if the supply to be furnished was for domestic purposes.

Extension of Powers and Duties of Local Authorities Under Public Health Act of 1936

The following is substituted for Sec. III of the Public Health Act of 1936. Sec. 3 of the Rural Water Supply and Sewerage Act of 1944 is eliminated.

III.—(1) It shall be the duty of every local authority—

(a) to take from time to time such steps as may be necessary for ascertaining the sufficiency and wholesomeness of water supplies within their district;

(b) to provide a supply of wholesome water in pipes to every part of their district in which there are houses or schools, and to take the pipes affording that supply to such point or points as will enable the houses or schools to be connected thereto at a reasonable cost. . . .

(c) to provide a supply of wholesome water otherwise than in pipes to every part of their district in which there are houses or schools and to which it is not practicable to provide a supply in pipes at a reasonable cost, and in which danger to health arises from the insufficiency or unwholesomeness of the existing supply and a public supply is required and can be provided at a reasonable cost, and to secure that such supply is available within a reasonable distance of every house and school in that part of their district.

* The National Trust means the National Trust for Places of Historic Interest or National Beauty, incorporated by the National Trust Act of 1907.

Questions raised as to where pipes shall be extended or whether the cost of extending the supply is reasonable may be determined by the Minister upon request of the county council or by ten or more local government electors in the district.

The obligations imposed upon local authorities by this section are also included in those of joint water boards.

Section 137 of the Public Health Act of 1936 is revised so that a local authority shall reject plans for any house submitted to it unless provision is made for a satisfactory water supply for it either by connecting to a public supply, by piping the supply into the house from some other source or by providing a water supply within reasonable distance of the house. In case of dispute regarding the matter it can be determined upon application by a court of summary jurisdiction.

Section 138 of the Public Health Act of 1936 is revised so that a local authority may, where it determines a house does not have a satisfactory water supply, require the owner within a specified time either to connect to a public water supply, to pipe water into the house from some other source or to provide a supply within reasonable distance of the house. Appeal to a court of summary jurisdiction within 28 days of receipt of such a notice from the local authority is provided the owner.

Modernization of Water Works Code

The Minister may incorporate in an order made under certain sections of this act such provisions contained in the Third Schedule of this act (see page 94) as appear to him appropriate.

The Minister may by order apply the provisions of the Third Schedule to this act or any of them to any statutory water undertakers supplying water under a local enactment, provided that he shall not make such an order within five years after the passage of the act except upon the application of the undertakers concerned.

The Minister, upon application of any statutory water undertakers, may repeal or amend any local enactment relating to the supply of water by the undertakers, except that the order may not apply to any local enactment regarding compensation water or cover any matter which could be more appropriately handled otherwise under the provisions of this act.

Miscellaneous

Water undertakers are authorized to discharge water from any of their reservoirs, pipelines or wells which they are constructing, repairing, cleaning, etc., into any watercourse, subject to due notice to and to the consent of any catchment, fishery, rivers or navigation board whose waterways are affected. Certain minor exceptions are permitted where consent and notice are not required. Where the consent of any affected board is believed withheld unreasonably the matter shall be referred to an arbitrator appointed, in default of agreement, by the President of the Institution of Civil Engineers. Unless disapproval of an application to discharge such water is received within seven days of receipt of the same, approval is deemed given.

Downstream abutting landowners or mill owners within 3 miles of the point of discharge of any such water must, if they request the water undertakers, be notified as to the particulars of the discharge of such water.

Water undertakers shall take all necessary steps to keep such water discharged by them under the provisions of this section free from mud, silt and

solid and polluting, offensive or injurious matters.

Railway or navigational authority property may not be damaged and a highway may not be damaged or flooded by the discharge of water permitted under this section of the act.

The water undertakers shall compensate public authorities and private individuals for any damages to their properties or expenses incurred on account of the discharge of water permitted as above.

Any question as to the amount of the compensation to be so paid shall be referred to an arbitrator to be appointed, in default of agreement, by the Minister.

Statutory water undertakers may, upon request of any person to whom they supply or propose to supply water, sell or hire to him any water fittings or install, repair or alter any water fittings. The cost of such work or fittings may be recovered, if necessary, summarily as a civil debt. Water fittings let for hire bearing the undertaker's mark shall remain the undertaker's property and be removable by him.

Where the water undertakers are a local authority the charges shall be adjusted to meet the expenditure.

Any person who wilfully or negligently injures any fitting belonging to the water undertakers shall upon conviction be subject to a fine of £5 and the undertakers may repair such injury done and recover the expenses reasonably incurred summarily as a civil debt.

The owner or occupier of any premises can require the statutory water undertakers serving the area to extend his mains to the area if the annual water rates received therefrom are not less than a prescribed fraction of the cost incurred by the undertakers in extending their service to the area and if the owner of the premises agrees to take a supply of water for a prescribed period. Where the annual water charges will not meet the cost of extending the service the local authority is authorized to make up the difference for a maximum period of twelve years or until the returns from the water supplied equal the prescribed fraction of the cost. Any two or more local authorities can combine for the purpose aforesaid. Water undertakers must bring water to the required area within three months after the receipt of the tender of such an undertaking as the above or be guilty of an offense under the act.

Where an owner of land proposes to erect thereon buildings for which a supply of water for domestic purposes is needed he may require the water undertaker serving the area in which the land is located to bring water thereto, provided he undertakes to pay annually one-eighth of the cost of extending the mains (less the receipts from the water used from said mains) until the annual receipts from the water used from said mains equal said sum, or for twelve years, whichever first occurs, and provided that (except where the owner is a public authority) he deposits with the undertaker such security, not exceeding the cost of the necessary construction, as is required to insure the payment of aforesaid annual sum. The water undertaker shall pay interest at the prescribed rate on any such deposits. Again, extension of the service by the undertakers within three months is mandatory.

Water charges are payable by the occupier of premises except where the owner is liable by a special enactment.

Water charges may be recovered summarily as a civil or contract debt. Water to premises may be cut off seven days after the owner is sent his water bill if he fails to pay it, except in case of dispute as to the amount of or liability for the bill when the cut-off must await the decision of the court.

Where an owner is not the occupier of a premises but is liable for the water bill by enactment or agreement, the water to the premises cannot be cut off because of failure to pay the due bill. However, the bill can be collected either from the owner by usual procedure or from the occupier upon notice to the latter to pay the bill out of rents due or to become due the owner, except the occupier cannot be required to pay at any one time more than the amount of rent he owes. The occupier is legally empowered to deduct such sums as he pays for the water charges from any rents due the owner. The water can be cut off should the occupier fail to pay the due water bill after receipt of due notice.

Where a water undertaker cuts off the water supply from an inhabited house the local authority must be notified within 48 hours. Upon failure to do so the undertaker is liable to a fine of not over £10. This provision does not apply to the administrative county of London.

The Minister may alter water rates and charges upon application to him by a water undertaker supplying water under a local enactment, by a local authority whose county is served by such an undertaker, or by 20 or more persons supplied by such an undertaker, provided, that where the undertaker is a company, he shall not make such alteration if it endangers the financial stability of the company. Such alteration in rates shall, other than in exceptional cases, not be made oftener than every five years.

Statutory water undertakers are required to file with the Minister, in such form as required by him, signed and certified annual statements of their undertakings. A copy has to be filed with the clerk of the local authority of every county or district wherein the undertaker operates.

Section 43 applies to the appointing of directors of companies and changes in the Companies Clauses Consolidation Act of 1845. Notably the Chief Engineer, General Manager or Secretary of a company can legally be a director of the company.

Part V—General

Should any officer or servant of any statutory water undertaker lose his position or have his salary reduced because of an order issued under this act, he shall, unless compensated otherwise, be entitled to receive compensation from such statutory undertakers as may be specified in the order; and for the purpose of any claim for compensation under this section, the provisions of Sec. 150 of the Local Government Act of 1933 shall have effect.

Severe penalities are provided for persons supplying false information in connection with the keeping of any records or returns required or with obtaining a licence under the act.

Section 48 covers the conditions governing the right of entry upon premises by representatives of water undertakers.

The Minister is empowered to cause such inquiries as he may consider necessary to carry out his duties under the act. He is given the power to revoke any order he makes under the act. Regulations under the act prescribed by the Minister shall be laid before

Parliament as soon as possible after they are made, and if either House resolves within 40 days that the regulations shall be annulled, they shall cease to have effect without prejudicing anything previously done thereunder or the making of new regulations. Expenses incurred by him in carrying out his functions under the act are paid for out of Parliamentary appropriations.

Sections 54, 55 and 56 govern the method of issuing notices under the Third Schedule of the act.

No judge shall be disqualified from acting in cases under the act by reason only of his being liable to pay any rate or charge thereunder.

The act is cited as the Water Act, 1945. It became effective Oct. 1, 1945. It does not apply to Scotland or Northern Ireland.

Following the act proper are five schedules as follows:

First Schedule—Procedure for Making Orders, Approving Agreements and Making and Confirming By-Laws

Second Schedule—Compulsory Purchase Orders

Third Schedule (reprinted in full below)—Provisions To Be Incorporated in Orders Relating to Water Undertakings

Fourth Schedule—Amendments of the Public Health Act, 1936

Fifth Schedule—Enactments Repealed

These schedules supply the details of the procedure to be followed in the carrying out of the provisions of the act and are exceedingly interesting and informative. However, they are quite lengthy and all of them cannot, unfortunately, be included here. The Third Schedule, which contains much of value in the way of information and ideas, is reproduced in its entirety below.

THIRD SCHEDULE

Provisions To Be Incorporated in Orders Relating to Water Undertakings

Part I—Interpretation

1.—(1) In this schedule the following expressions shall, subject to any express provision or anything in the context to the contrary, have the meanings hereby respectively assigned to them, that is to say:

"Authorized" means authorized by the special act.

"Bridge authority" means:

(*a*) in the case of a county bridge, the county council;

(*b*) in the case of any other bridge maintainable at the public expense, the authority who are the highway authority in respect of the highway carried by the bridge.

"Building" includes a part of a building if that part is separately occupied.

"Building by-laws" means by-laws made under Part II of the Public Health Act, 1936, with respect to buildings, works and fittings, and includes by-laws made with respect to those matters under any corresponding enactment repealed by that act, or under any such enactment as amended or extended by a local act.

"Business" does not include a profession.

"Catchment board" and "catchment area," in relation to such a board have the same meanings as in the Land Drainage Act, 1930.

"Communication pipe" means:

(a) where the premises supplied with water abut on the part of the street in which the main is laid, and the service pipe enters those premises otherwise than through the outer wall of a building abutting on the street and has a stopcock placed in those premises and as near to the boundary of that street as is reasonably practicable, so much of the service pipe as lies between the main and that stopcock;

(b) in any other case, so much of the service pipe as lies between the main and the boundary of the street in which the main is laid,

and includes the ferrule at the junction of the service pipe with the main, and also

(i) where the communication pipe ends at a stopcock, that stopcock; and

(ii) any stopcock fitted on the communication pipe between the end thereof and the main.

"Consumer" means a person supplied, or about to be supplied, with water by the undertakers.

"County" means an administrative county.

"County district" means a non-county borough, an urban district or a rural district.

"Enactment" means any Act of Parliament, whether public, general, local or private, any statutory order or any provision in an Act of Parliament or statutory order.

"Factory" means a factory within the meaning of the Factories Act, 1937.

"Fire authority" has the same meaning as in the Fire Brigades Act, 1938.

"Fishery board" and "fishery district" have the same meanings as in the Salmon and Freshwater Fisheries Act, 1923.

"Highway authority" means, in the case of a highway maintainable at the public expense, the authority in whom that highway is vested.

"House" means a dwelling-house, whether a private dwelling-house or not, and includes any part of a building if that part is occupied as a separate dwelling-house.

"Land drainage authority" means a drainage authority within the meaning of the Land Drainage Act, 1930.

"Limits of supply," in relation to any water undertaking, means the limits within which the undertakers are for the time being authorized to supply water.

"Local authority" means the council of a borough or of an urban or rural district, and "district," in relation to the local authority of a borough, means that borough.

"Main" means a pipe laid by the undertakers for the purpose of giving a general supply of water as distinct from a supply to individual consumers and includes any apparatus used in connection with such a pipe.

"Minister" means Minister of Health.

"Navigation authority" means any person or body of persons, whether incorporated or not, having powers under an enactment to work, maintain, conserve, improve or control any canal or other inland navigation, navigable river, estuary, harbor or dock.

"Owner" means the person for the time being receiving the rackrent of the premises in connection with which the word is used, whether on his own account or as agent or trustee for any

other person, or who would so receive the same if those premises were let at a rackrent.

"Prescribed" means prescribed by the special act.

"Railway company" means any persons authorized by an enactment to construct, work or carry on a railway, and includes the London Passenger Transport Board.

"Rivers board" means a joint committee, board or other body, constituted under subsection (3) of Sec. 14 of the Local Government Act, 1888, or by or under a local act, for the purpose of exercising powers of a sanitary authority under the Rivers Pollution Prevention Act, 1876.

"Service pipe" means so much of any pipe for supplying water from a main to any premises as is subject to water pressure from that main, or would be so subject but for the closing of some tap.

"Sewerage authority" has the same meaning as in the Public Health Act, 1936.

"Special Act" means the enactment with which any provisions of this schedule are incorporated, with or without modifications, and includes those provisions as so incorporated.

"Statutory order" means an order or scheme made under an Act of Parliament, including an order or scheme confirmed by Parliament.

"Statutory undertakers" means any persons authorized by an enactment to construct, work or carry on any railway, canal, inland navigation, dock, harbor, tramway, gas, electricity, water or other public undertaking.

"Street" includes any highway, including a highway over any bridge, and any road, lane, footway, square, court, alley or passage, whether a thoroughfare or not.

"A supply of water for domestic purposes" means a sufficient supply for drinking, washing, cooking and sanitary purposes, but not for any bath having a capacity (measured to the center line of the overflow pipe, or in such other manner as the Minister may by regulations prescribe) in excess of 50 gal.; and includes—

(*a*) a supply for the purposes of a profession carried on in any premises the greater part whereof is used as a house; and

(*b*) where the water is drawn from a tap inside a house and no hosepipe or similar apparatus is used, a supply for watering a garden, for horses kept for private use and for washing vehicles so kept:

Provided that it does not include a supply of water for the business of a laundry or a business of preparing food or beverages for consumption otherwise than on the premises.

"Supply of water in bulk" means a supply of water for distribution by the undertakers taking the supply.

"Supply pipe" means so much of any service pipe as is not a communication pipe.

"Telegraphic line" has the same meaning as in the Telegraph Act, 1878.

"Trunk main" means a main constructed for the purpose of conveying water from a source of supply to a filter or reservoir, or from one filter or reservoir to another filter or reservoir, or for the purpose of conveying water in bulk from one part of the limits of supply to another part of those limits, or for the purpose of giving or taking a supply of water in bulk.

"Undertakers" means the persons whose water undertaking is authorized or regulated by the special act.

"Watercourse" includes all rivers, streams, ditches, drains, cuts, culverts, dikes, sluices, sewers (other than sewers vested in a local authority or joint board of local authorities) and passages through which water flows.

"Water fittings" includes pipes (other than mains), taps, cocks, valves, ferrules, meters, cisterns, baths, water-closets, soilpans and other similar apparatus used in connection with the supply and use of water.

(2) Any reference in this schedule to the persons having the control or management of a street or bridge shall be construed as a reference, in the case of a highway or bridge maintainable at the public expense, to the authority who are the highway authority, or, as the case may be, the bridge authority in respect thereof and, in the case of any other street or bridge, to the authority or person responsible for the maintenance thereof, or, if no authority or person is responsible therefor, to the owners of the soil of the street or, as the case may be, of the structure of the bridge.

(3) References in this schedule to any enactment shall be construed as including references to that enactment as amended by any subsequent enactment, including the Water Act, 1945.

Part II—Works and Lands

2. In the construction of any authorized works the undertakers may deviate laterally to any extent not exceeding the limits of deviation shown on the plans submitted to the Minister and, where on any street no such limits are shown, the boundaries of the street (including for this purpose any verge or roadside waste adjoining it) shall be deemed to be such limits, and they may also deviate vertically from the levels shown on the said plans to any extent:

Provided that

(*a*) no embankment for a reservoir shall be constructed at a greater height above the general surface of the ground than that shown on the said plans and 6 ft. in addition thereto; and

(*b*) except for the purpose of crossing a river, stream, canal, dike, watercourse or railway, or of crossing any lands where the consent of all persons having a legal interest therein has been obtained, no pipe or other conduit or aqueduct shall be raised above the surface of the ground otherwise than in accordance with the said plans.

3. The undertakers shall not construct any works for taking or intercepting water (other than works for intercepting foul water) from any lands acquired by them, unless the works are authorized by, and the lands on which the works are to be constructed are specified in, the special act or some other enactment.

4. Subject to the provisions of the last foregoing section and to any other provisions of the special act limiting the powers of the undertakers to abstract water, the undertakers, in addition to any works specifically authorized, may in, on or over any land for the time being held by them in connection with their water undertaking construct, lay or erect for the purposes thereof, or in connection therewith, and may maintain, such reservoirs, sluices, tanks, cisterns, aqueducts, tunnels, culverts, mains, pipes, engines, pumps, machinery, filters, treatment plant, buildings and things for, or in connection with, the supply of water as they deem necessary:

Provided that any electrical works or apparatus constructed, laid or erected under this section shall be so constructed, laid or erected, and so maintained and used, as to prevent interference with any telegraphic line belonging to or used by the Postmaster General, or with telegraphic communication by means of any such line.

5.—(1) For the purpose of establishing telegraphic, telephonic or other electrical communication between their offices and any part of their works, or between different parts of their works, the undertakers may lay and erect in, on or over any highway, and, with the consent of the owners and occupiers of any other land, in, on or over that land, such wires, posts, conductors and other apparatus as they deem necessary and the provisions of the special act relating to the breaking open of streets by the undertakers shall, with any necessary modification or adaptation, apply as respects any highway in relation to the laying, erection and maintenance of any such wires, posts, conductors or other apparatus:

Provided that the undertakers shall not lay or erect any such wires, posts, conductors or other apparatus except with the consent of the local authority and highway authority concerned and in accordance with such conditions as either of those authorities may attach to their consent, but such consent shall not be unreasonably withheld nor shall unreasonable conditions be attached thereto, and any question whether a withholding of consent or a condition is reasonable or not shall be referred to an arbitrator to be appointed, in default of agreement, by the President of the Institution of Civil Engineers.

(2) The undertakers shall at any time at their own expense remove any wires, posts, conductors or other apparatus laid or erected by them under the provisions of this section if they are required so to do by the local authority or a highway authority for the purpose of enabling any widening or other improvement to be carried out to a street or highway.

(3) Wires, posts, conductors or other apparatus laid or erected by the undertakers under the provisions of this section shall not be used in contravention of the exclusive privilege conferred upon the Postmaster General by the Telegraph Act, 1869, or be installed or worked in contravention of the provisions of the Wireless Telegraphy Acts, 1904 to 1926, and shall be so constructed, maintained and used as to prevent interference with any telegraphic line belonging to or used by the Postmaster General, or with telegraphic communication by means of any such line.

(4) Where the undertakers propose, in the exercise of their powers under this section, to lay or erect any wires, posts, conductors or other apparatus over, under or in the vicinity of any electric line belonging to any electricity undertakers, the undertakers shall take all reasonable precautions so as not injuriously to affect, whether by induction or otherwise, the working or user of, or the currents in, the electric line.

Any question which may arise between the undertakers and any electricity undertakers under this subsection shall be determined by an arbitrator to be agreed between the undertakers and the electricity undertakers or, failing agreement, to be appointed by the President of the Institution of Electrical Engineers, and the arbitrator may direct the undertakers to make any alterations in their wires, posts, conductors or other apparatus so as to

comply with the provisions of this subsection and the undertakers shall make those alterations accordingly.

In this subsection the expressions "electric line" and "electricity undertakers" have the same respective meanings as in the Electricity (Supply) Acts, 1882 to 1936.

(5) Where the undertakers propose, in the exercise of their powers under this section, to lay or erect any wires, posts, conductors or other apparatus which will cross or interfere with any watercourse or works vested in, or under the control of, a land drainage authority, they shall give notice of their proposals to that authority and if within 28 days that authority serve on the undertakers notice of objection to their proposals, the undertakers shall not proceed with their proposals unless all objections so made are withdrawn or the Minister after a local inquiry has approved the proposals either with or without modification:

Provided that this subsection shall not apply in relation to any wires, posts, conductors or other apparatus which the undertakers propose to lay or erect in or on a bridge carrying a highway across such a watercourse as aforesaid.

6. Any person who wilfully obstructs a person engaged by, or under authority of, the undertakers in setting out the line, level or site of any authorized works, or knowingly pulls up any peg or stake driven into the ground for the purpose of setting out such line, level or site, or knowingly defaces or destroys anything made or erected for that purpose, shall be liable to a fine not exceeding £5.

7.—(1) Where the undertakers are empowered by the special act to execute any underground works, they may, in lieu of purchasing land compulsorily for the purpose of executing those works, be authorized by means of a compulsory purchase order made by the undertakers and confirmed by the Minister to purchase only such easements and rights over or in that land as may be sufficient for the said purpose and the provisions of the Second Schedule to the Water Act, 1945, shall apply, with such adaptations as may be necessary, to any compulsory purchase order made under this section.

(2) The undertakers shall not be required or, except by agreement, be entitled to fence off or sever from adjoining lands any lands in respect of which they have purchased only easements or rights under the provisions of this section, and subject to those easements or rights and to any other restrictions imposed by the special act, the owners or occupiers for the time being of those lands shall have the same rights of using and cultivating them as if that act had not been passed.

8. Persons empowered by the Lands Clauses Acts to sell and convey, or release, any lands may, subject to the provisions of those acts and of the special act, grant to the undertakers any easement or right required for the purposes of the special act over or in those lands, and the provisions of the Lands Clauses Acts with respect to lands and rentcharges shall, so far as applicable, apply in relation to such grants and to such easements and rights:

Provided that nothing in this section shall be construed as empowering persons to grant any easement or right of water in which any other person has an interest, unless that other person concurs in the grant.

9.—(1) Any private right of way over land which the undertakers are

authorized to acquire compulsorily shall, if they so resolve and give notice of their resolution to the owner of the right, be extinguished as from the acquisition by them of the land, or as from the expiration of one month from the service of the notice, whichever may be the later.

(2) The undertakers shall pay compensation to all persons interested in respect of any such right so extinguished and such compensation shall, in case of dispute, be settled in manner provided by the Lands Clauses Acts with respect to the taking of lands otherwise than by agreement.

Part III—Compensation Water

10.—(1) During the construction of any authorized impounding reservoir the undertakers may, subject as hereinafter provided, take from any stream to be impounded thereby such water as they may require:

Provided that, before taking any water from the stream, they shall, on an approved site, construct an approved gage to gage the flow of the stream and, while the flow of water through or over the gage is less than the prescribed flow, they shall not take any water.

(2) After the completion of the reservoir the undertakers shall, at an approved point within such limits as may be prescribed, discharge into the stream from, or from streams feeding, the reservoir during every day of 24 hours reckoned from midnight in a uniform and continuous flow a quantity of water not less than the prescribed quantity, and, for the purpose of gaging such discharge, they shall construct and maintain in good order approved gages on approved sites.

(3) Where the undertakers are authorized to take any water from any stream, they shall, before taking any such water, construct on approved sites approved gages to gage the quantity of water taken and the flow of the stream, and they shall not take any water in excess of the quantity authorized to be taken or while the flow of water through or over the gage is less than the prescribed flow.

(4) If the undertakers—

(*a*) fail to construct or maintain in good order any such gage as aforesaid, or refuse to allow any person interested to inspect and examine any such gage or any records made thereby or kept by them in connection therewith or to take copies of any such records; or

(*b*) take any water from the stream contrary to the provisions of subsection (1) or subsection (3) of this section, or fail to comply with the requirements of subsection (2) of this section with respect to the discharge of water into the stream,

they shall, without prejudice to their civil liability, if any, to a person aggrieved, be liable, in the case of an offense under paragraph (*a*) of this subsection, to a fine not exceeding £50, in respect of each day on which the offense has been committed or has continued, and in the case of an offense under paragraph (*b*) of this subsection

(i) on summary conviction, to a fine not exceeding £50 in respect of each such day; and

(ii) on conviction on indictment, to a fine not exceeding £500 in respect of each such day.

(5) In this section, the expression "gage" includes a gage weir or other apparatus for measuring the flow of water, and the expression "approved" means approved by the Minister; and,

for the purposes of this section, a catchment board, a fishery board, a rivers board and a navigation authority shall be deemed to be interested in the flow of water in, and the discharge of water into, any stream within their area or district, or, as the case may be, forming part of their system of navigation or any stream feeding such a stream or any part of that system and shall be deemed to be aggrieved by the commission of an offense under this section in relation to any such stream.

(6) The foregoing provisions of this section shall be deemed to have been accepted by all persons interested as full compensation for all water impounded by the authorized works, except in respect of any land between the foot of the embankment of the reservoir and the point of discharge approved for the purposes of subsection (2) of this section.

(7) Subject to the provisions of Sec. 5 of the Criminal Justice Administration Act, 1914, any fine recovered under this section on the complaint of a fishery board or of an officer of, or person authorized by, a fishery board shall, as to the whole or such part thereof as the court may determine, be paid to the board in respect of the costs of the prosecution.

Part IV—Minerals Underlying Water Works

11. Where the undertakers purchase any land they shall become entitled to such parts of any mines of coal, ironstone, slate or other minerals under that land as it may be necessary for them to dig, carry away or use in the construction of any water works authorized by the special act, but, save as aforesaid, they shall not by virtue only of their purchase of the land become entitled to any such mines or minerals, which shall, save as aforesaid, be deemed to be excepted from the conveyance of the land unless expressly mentioned therein as conveyed thereby.

12.—(1) The undertakers shall, within six months after the first occasion on which any pipes, or other conduits, or underground works are laid or constructed by them after this section is incorporated with their enactments, cause the course and situation of all existing pipes or other conduits for the collection, passage, or distribution of water and underground works belonging to them to be marked on a map (drawn on a scale not less than 6 in. to 1 mile), and shall, from time to time, within six months after the making of any alterations or additions, cause the said map to be so corrected as to show the course and situation of all such pipes and conduits, and underground works for the time being belonging to them, and the map, or a copy thereof, bearing the date of its preparation and of the last occasion on which it was corrected shall be kept at the office of the undertakers.

In this subsection the expression "pipes" does not include service pipes.

(2) The said map shall at all reasonable hours be open to inspection by any person interested free of charge.

13. Subject to any agreement to the contrary, if the owner, lessee, or occupier of any mines of coal, ironstone, slate or other minerals lying under the reservoirs or buildings of the undertakers, or any of their pipes or other conduits or underground works shown on the map referred to in the last foregoing section, or lying within the prescribed distance therefrom, or, if no distance be prescribed, within 40 yd. therefrom, desires to work the said

mines or minerals, he shall give to the undertakers 30 days' notice of his intention so to do.

14.—(1) Upon receipt of such a notice as aforesaid, the undertakers may cause the said mines or minerals to be inspected by any person appointed by them for the purpose, and if it appears to them that the working thereof is likely to damage any of their reservoirs or buildings, or pipes, or other conduits or underground works shown on the said map, and if they are willing to pay compensation for the mines or minerals to the owner, lessee or occupier thereof, then he shall not work them, and the amount of the compensation to be paid shall, in the case of dispute, be determined by arbitration.

(2) If the undertakers have not before the expiration of the said 30 days stated their willingness to treat with the owner, lessee, or occupier for the payment of compensation, it shall be lawful for him to work the said mines and minerals, and to drain them, by means of pumps or otherwise, as if the special act had not been passed, so, however, that no wilful damage be done to any of the said property or works of the undertakers and that the mines and minerals be not worked in an unusual manner.

(3) Any damage or obstruction occasioned to any of the said property or works of the undertakers by the working of such mines or minerals in an unusual manner shall be forthwith repaired or removed, and the damage made good, by the owner, lessee, or occupier of the mines or minerals, and if such repair or removal be not effected forthwith, or, if the undertakers deem it necessary to take action without waiting for the work to be done by the owner, lessee, or occupier, the undertakers may execute the work, and recover from the owner, lessee, or occupier the expenses reasonably incurred by them in so doing.

15. If the working of any such mines or minerals as aforesaid lying under the reservoirs or buildings of the undertakers, or any of their pipes or other conduits or underground works shown on the map referred to in Sec. 12 of this schedule, or lying within the above-mentioned distance therefrom, mentioned in Sec. 13 of this schedule, be prevented as aforesaid by reason of apprehended injury thereto, the respective owners, lessees, and occupiers of the mines or minerals may cut and make such and so many airways, headways, gateways, or water levels through the mines, measures, or strata the working whereof is so prevented as may be requisite to enable them to ventilate, drain, and work any mines or minerals on each or either side thereof, but no such airway, headway, gateway, or water level shall be of greater dimensions or sections than the prescribed dimensions or sections, or, if no dimensions are prescribed, 8 ft. wide and 8 ft. high, nor be cut or made upon any part of the said property or works of the undertakers so as to cause injury thereto.

16.—(1) Subject to any agreement to the contrary, the undertakers shall from time to time pay compensation to the owner, lessee, or occupier of any mines of coal, slate, ironstone, and other minerals lying on both sides of any reservoir, building, pipe, or other conduit, or other works of the undertakers for any loss and additional expense incurred by him by reason of the severance of the lands above such mines or minerals by the reservoir or other works, or by reason of the continuous working of such mines or minerals being interrupted as aforesaid, or

by reason of their being worked under the restrictions imposed by the special act, and also for any such mines or minerals not purchased by the undertakers as cannot be worked or won by reason of the making and continuance of the said works, or by reason of such apprehended injury from the working thereof as aforesaid.

(2) The amount of any such compensation shall, in the case of dispute, be determined by arbitration.

17. For the purpose of ascertaining whether any such mines or minerals as aforesaid are being, have been or are about to be worked so as to damage any of their said works, any authorized officer of the undertakers, after giving 24 hours' notice and on producing, if so required, some duly authenticated document showing his authority, may enter upon any lands in, on or near which the works are situate, and under which they know or suspect that any such mines are being, have been or are about to be worked, and may enter any such mines and the works connected therewith, using for their entry, inspection and return any apparatus or machinery belonging to the owner, lessee, or occupier of the mines, and may use all necessary means for discovering the distance from the said works to the parts of the mines which are being, have been or are about to be worked.

18. Nothing in the special act shall exempt the undertakers from liability to any action or other legal proceeding to which they would have been liable in respect of any damage or injury done or occasioned to any mines by means, or in consequence, of their water works, if those works had been constructed or maintained otherwise than by virtue of the special act.

Part V—Power to Lay Mains, etc.

19.—(1) The undertakers may within their limits of supply and also, subject to the provisions of the next succeeding section, outside those limits, lay a main

(*a*) in any street, subject, however, to the provisions of Part VI of this schedule; and

(*b*) with the consent of every owner and occupier of any land not forming part of a street and with the consent of the local authority of the district in which that land is situate and also of the highway authority concerned, if the main will be laid within 220 ft. of any highway, in, on or over that land,

and may from time to time inspect, repair, alter or renew, or may at any time remove, any main laid down by them, whether by virtue of this section or otherwise:

Provided that a consent required for the purposes of this subsection shall not be unreasonably withheld and any question whether such a consent is, or is not, unreasonably withheld shall be referred to and determined by the Minister.

(2) Where the undertakers propose in the exercise of their powers under this section to lay a main which will cross or interfere with any watercourse or works vested in, or under the control of, a land drainage authority, they shall give notice of their proposals to that authority, and, if within 28 days that authority serve on the undertakers notice of objection to their proposals, the undertakers shall not proceed with their proposals unless all objections so made are withdrawn, or the Minister after a local inquiry has approved the proposals, either with or without modification:

Provided that this subsection shall not apply in relation to a main which the undertakers propose to lay in a bridge carrying a highway across such a watercourse as aforesaid.

(3) Where the undertakers, in the exercise of their powers under this section, lay a main in, on or over any land not forming part of a street, or inspect, repair, alter, renew, or remove a main laid in, on or over any such land, they shall from time to time pay compensation to every person interested in that land for any damage done to, or injurious affection of, that land by reason of the inspection, laying, repair, alteration, renewal or removal of the main.

Any dispute as to the amount of compensation to be paid under this subsection shall be referred to arbitration.

(4) The undertakers may erect and maintain in any street notices indicating the position of underground water fittings used for controlling the flow of water through their mains, whether laid by virtue of this section or otherwise, and may affix such a notice to any house or other building, wall or fence.

(5) For the purposes of this section, a private street within the curtilage of a factory shall be deemed not to be, or form part of, a street.

20.—(1) Where the undertakers, in the exercise of their powers under the last foregoing section, propose to lay a main outside their limits of supply, the provisions of that section shall apply, and the undertakers shall, in addition to giving any notice required by that section

(*a*) in the case of each county borough or county district in which they propose to lay a main, publish by advertisement in a local newspaper circulating in the borough or district a notice describing the nature of their proposals and specifying the land directly affected thereby, and naming a place where a plan illustrative of their proposals may be inspected at all reasonable hours by any person free of charge; and

(*b*) serve, not later than the date of the publication of the advertisement, a copy of the notice on the local authority of the borough or district and on the highway authority for any highway in which they propose to lay a main.

(2) If, within 28 days after the publication of the notice referred to in the last foregoing subsection, notice of objection to their proposals is served on the undertakers by any such local authority or highway authority as aforesaid, they shall not proceed with their proposals, unless all objections so made are withdrawn, or the Minister, after a local inquiry, has approved the proposals, either with or without modification.

(3) The foregoing provisions of this section with respect to the publication and service of, and objections to, such additional notices as are therein referred to shall not apply where the work which undertakers propose to carry out outside their limits of supply consists only of the laying of a main in a highway maintainable at the public expense and they have obtained the consent of the local authority of the county borough or county district within which that highway is situated and also, where that authority is not the highway authority for the highway in question, the consent of that highway authority.

21.—(1) The undertakers may in any street within their limits of supply lay such service pipes with such stop-

cocks and other fittings as they deem necessary for supplying water to premises within the said limits, and may from time to time inspect, repair, alter, or renew, and may at any time remove, any service pipe laid in a street whether by virtue of this section or otherwise.

(2) Where a service pipe has been lawfully laid in, on or over any land not forming part of a street, the undertakers may from time to time enter upon that land and inspect, repair, alter, renew or remove the pipe or lay a new pipe in substitution therefor, but shall pay compensation for any damage done by them.

Any dispute as to the amount of compensation to be paid under this subsection shall be determined by arbitration.

Part VI—Breaking Open Streets, etc.

22. Subject to the provisions of this part of this schedule, the undertakers may within their limits of supply for the purpose of laying, constructing, inspecting, repairing, renewing or removing mains, service pipes, plant or other works, and outside those limits for the purpose of laying any mains which they are authorized to lay and of inspecting, repairing, renewing or removing mains, break open the roadway and footpaths of any street, and of any bridge carrying a street, and any sewer, drain or tunnel in or under any such roadway or footpath, and may remove and use the soil or other materials in or under any such roadway or footpath:

Provided that they shall in the exercise of the powers conferred by this section cause as little inconvenience and do as little damage as may be, and for any damage done shall pay compensation to be determined, in case of dispute, by arbitration.

23. Not less than fourteen clear days before they commence to break open the roadway or footpath of any street or bridge, or any sewer, drain or tunnel, the undertakers shall give notice of their intentions, and of the time when they propose to commence the work, to the persons having the control or management of the street, bridge, sewer, drain or tunnel in question, or to some officer of those persons authorized by them to receive such notices:

Provided that

(*a*) in cases of emergency arising from defects in any pipes, plant or works, it shall be sufficient if the notice required by this section is given as soon as possible after the necessity for the work becomes known to the undertakers;

(*b*) where the roadway or footpath is broken open for the purposes mentioned in the last but one foregoing section of this schedule, the notice shall be 72 hours instead of fourteen days.

24.—(1) Subject to the provisions of this section, the undertakers shall not, save in such cases of emergency as aforesaid, break open the roadway or footpath of any street or bridge, or any sewer, drain or tunnel, except under the supervision of, and in accordance with plans approved by, the persons having the control or management thereof, or their authorized officer:

Provided that, if any difference arises in connection with the plans submitted for approval, that difference shall be referred to an arbitrator to be appointed, in default of agreement, by the Minister, or, if he thinks fit, by the

President of the Institution of Civil Engineers, and, in cases where a sewer or drain is affected, the arbitrator may direct the undertakers to execute such work as he may deem necessary for preventing any temporary interruption of drainage through that sewer or drain, and the undertakers shall comply with any direction so given.

(2) Notwithstanding anything in the last foregoing subsection, if the persons having the control or management of a street, bridge, sewer, drain or tunnel, or their authorized officer, after having received such notice of the undertakers' intentions as is mentioned in the last foregoing section, fail to question the sufficiency or propriety of any plans submitted to them, or fail to submit any alternative plans to the undertakers, or fail to attend and exercise supervision over the work, the undertakers may proceed to carry out the work.

25.—(1) Except in cases of emergency arising from defects in pipes, plant or works, the roadway or footpath of a street or bridge which is under the control or management of, or maintainable by, a railway company or navigation authority shall not be broken open without their consent, but that consent shall not be unreasonably withheld, and any question whether or not consent is unreasonably withheld shall be referred to and determined by the Minister.

(2) Where the undertakers propose to break open the roadway or footpath of any length of street which forms a level crossing, or crosses over or under a railway or other works of a railway company or navigation authority, and which is not under the control or management of the railway company or navigation authority, they shall give to the railway company or navigation authority the like notice as they are required by the last but one foregoing section to give to the persons having the control or management of the street and, if and in so far as the proposed work is likely to affect the structure of any bridge or other works belonging to the railway company or navigation authority, shall carry out the work to the reasonable satisfaction of the engineer or other authorized officer of the railway company or navigation authority in accordance with plans approved by him.

Any dispute arising under this subsection between the persons proposing to execute work and a railway company or navigation authority, shall be referred to an arbitrator to be appointed, in default of agreement, by the President of the Institution of Civil Engineers.

(3) The last foregoing subsection shall, with any necessary adaptation, apply in relation to a level crossing which belongs to persons not being a railway company or navigation authority, as it applies in relation to a level crossing belonging to such a company or authority.

(4) For the protection of persons entitled to the benefit of Sec. 32 of the Tramways Act, 1870 (which relates to the rights of authorities and companies, etc., to open roads), that section shall be construed as applying to operations authorized by the special act, and in the said section as so applied any reference to a tramway shall be construed as including a reference to a trolley vehicle system.

(5) Nothing contained in this section for the protection of owners of level crossings shall affect the decision of any question which may arise as to

the legality of the construction of, or the right to continue, any level crossing.

26.—(1) When, for the purpose of executing any work, the undertakers break open the roadway or footpath of any street or bridge, or any sewer, drain, or tunnel, they shall with all convenient speed and to the reasonable satisfaction of the persons having the control or management thereof complete the work and fill in and consolidate the ground, and reinstate and make good the roadway or footpath, or the sewer, drain, or tunnel, as the case may be, and remove all rubbish resulting from their operations, and shall, after replacing and making good the roadway or footpath, keep it in good repair for three months, and for such further time, if any, not being more than twelve months in the whole, as the soil may continue to subside.

(2) So long as any such roadway or footpath remains broken open or obstructed, the undertakers shall make adequate arrangements for the control of traffic and shall cause the roadway or footpath to be properly fenced and guarded at all times and to be efficiently lighted between the hours of sunset and of sunrise.

27.—(1) If the undertakers fail to comply with, or contravene, any of the foregoing provisions of this part of this schedule, they shall, without prejudice to their civil liability, if any, to a person aggrieved, be liable to a fine not exceeding £5, and to a further fine not exceeding £5 for each day on which the offense continues after notice thereof has been given to them by, or by an officer or agent of, the persons aggrieved.

(2) If the undertakers fail to comply with any of the requirements of the last foregoing section, the persons having the control or management of the street, bridge, sewer, drain or tunnel in question, may in addition to, or in lieu of, taking proceedings under the last foregoing subsection, themselves execute any work necessary to remedy the default and may recover the expenses reasonably incurred by them in so doing from the undertakers summarily as a civil debt.

28.—(1) The provisions of this part of this schedule shall apply in relation to any land within the limits of a street, but not included in a roadway or footpath thereof, as if that land were, or formed part of, a footpath of the street.

(2) In this part of this schedule the expression "persons having the control or management" shall, in relation to a street not maintainable at the public expense, be deemed to include the authority by whom the street would be maintainable if it became a highway maintainable at the public expense and, accordingly, any notice required by Sec. 23 of this schedule and a copy of the plans referred to in Sec. 24 thereof shall be served on that authority, but the authority shall not take any action under subsection (2) of the last foregoing section except at the request and on behalf of the other persons having the control or management of the street, bridge, sewer, drain or tunnel in question.

Part VII—Supply of Water for Domestic Purposes

29.—(1) The undertakers shall lay any necessary mains and bring water to any area within the limits of supply if they are required to do so by such number of owners and occupiers of premises in that area who require a supply

of water for domestic purposes that the aggregate amount of water rates payable annually by those owners and occupiers in respect of those premises at the rates for the time being charged by the undertakers will not be less than one-eighth of the expense of providing and laying the necessary mains, and if those owners and occupiers agree severally with the undertakers to take a supply of water for three years at least.

(2) If the undertakers, after receipt of a requisition which satisfies the provisions of the last foregoing subsection and after tender to them of an agreement which satisfies those provisions, do not before the expiration of three months lay the necessary mains and bring water to the area in question in accordance with the requisition, they shall, unless they show that the failure was due to unavoidable accident or other unavoidable cause, be liable to a fine not exceedingly £50 and to a further fine not exceeding £5 for each day on which their default continues after conviction therefor.

30.—(1) An owner or occupier of any premises within the limits of supply who has complied in respect of those premises with the provisions of Part X of this schedule with respect to the laying of a supply pipe and payment or tender of the water rate shall be entitled to demand and receive from the undertakers a supply of water sufficient for domestic purposes for those premises:

Provided that nothing in the special act shall be construed as entitling any person to demand a supply of water from a trunk main.

(2) Subject as hereinafter provided, if the undertakers make default in furnishing a supply of water for domestic purposes to a person who is entitled to demand and has demanded such a supply, or fail to maintain the supply during any period in respect of which the water rate therefor has been paid or tendered, they shall, without prejudice to their civil liability, if any, to the person aggrieved, be liable to a fine not exceeding £5 and to a further fine not exceeding 40s. for each day on which the default continues after notice thereof from the person aggrieved:

Provided that the undertakers shall be under no such liability if the failure to furnish or maintain a supply is due to

(*a*) frost, drought, unavoidable accident or other unavoidable cause, or the execution of necessary works; or

(*b*) failure of the person aggrieved to comply with any enactment relating to, or by-law of, the undertakers.

31. The undertakers shall provide in their mains and communication pipes a supply of wholesome water sufficient for the domestic purposes of all owners and occupiers of premises within the limits of supply who under the special act are entitled to demand a supply for those purposes.

Part VIII—Supply of Water for Public Purposes

32. The undertakers shall, at the request of the fire authority concerned, fix fire hydrants on their mains (other than trunk mains) at such places as may be most convenient for affording a supply of water for extinguishing any fire which may break out within the limits of supply, and shall keep in good order and from time to time renew every such hydrant.

Any difference as to the number or proper position of such hydrants shall be referred to and determined by the Minister.

33. As soon as any such hydrant is completed, the undertakers shall, if required by the fire authority, deposit a key thereof at each place within the limits of supply where any public fire engine is kept, and in such other places as may be appointed by the fire authority.

34. The cost of such hydrants as aforesaid and of fixing, maintaining and renewing them, and of providing such keys as aforesaid, shall be defrayed by the fire authority.

35. The undertakers shall, at the request and expense of the owner or occupier of any factory or place of business situated in, or near to, a street in which a pipe of the undertakers is laid (not being a trunk main and being of sufficient dimensions to carry a hydrant), fix on the pipe and keep in good order and from time to time renew one or more fire hydrants, to be used only for extinguishing fires, as near as conveniently may be to that factory or place of business, and shall also at his expense comply as respects each such hydrant with the requirements of the last but one foregoing section.

36. The undertakers shall allow all persons to take water for extinguishing fires from any pipe of the undertakers on which a hydrant is fixed, without payment.

37.—(1) In every pipe of the undertakers on which a hydrant is fixed the undertakers shall provide a supply of water for cleansing sewers and drains, for cleansing and watering highways, and for supplying any public pumps, baths or washhouses.

(2) A supply of water for the said purposes shall be provided at such rates, in such quantities and upon such terms and conditions as may be agreed between the local authority, highway authority or sewerage authority concerned and the undertakers, or as, in default of agreement, may be determined by the Minister.

38. If the undertakers fail to comply with any of their obligations under this part of this schedule, except when prevented by frost, drought, unavoidable accident or other unavoidable cause, or during the execution of necessary works, they shall be liable to a fine not exceeding £50, and to a further fine not exceeding £5 for each day during which such failure continues after notice thereof from the authority or person concerned.

Part IX—Constancy and Pressure of Supply

39.—(1) Subject as hereinafter provided, the undertakers shall cause the water in all pipes on which hydrants are fixed, or which are used for giving supplies for domestic purposes, to be laid on constantly and at such a pressure as will cause the water to reach to the top of the top-most storey of every building within the limits of supply:

Provided that

(*a*) nothing in this section shall require them to deliver water at a height greater than that to which it will flow by gravitation through their mains from the service reservoir or tank from which the supply in question is taken; and

(*b*) they may in their discretion determine the service reservoir or tank from which any supply is to be taken.

(2) If the undertakers fail to comply with the foregoing requirements of this section, except when prevented by frost, drought, unavoidable accident or other unavoidable cause, or during the

execution of necessary works, they shall, without prejudice to their civil liability, if any, to a person aggrieved, be liable to a fine not exceeding £10 and to a further fine not exceeding 40*s*. for each day during which the failure continues after notice thereof from that person:

Provided that proceedings for the recovery of a fine shall not be instituted under this subsection by more than one person in respect of the same period of failure.

Part X—Laying and Maintenance of Supply Pipes and Communication Pipes

40. An owner or occupier of any premises within the limits of supply who desires to have a supply of water for his domestic purposes from the water works of the undertakers, shall, subject as hereinafter provided, comply with the following requirements:

(*a*) he shall give to the undertakers fourteen days' notice of his intention to lay the necessary supply pipe and at, or before, the time of giving such notice shall pay or tender to them such sum as may be payable in advance by way of water rate in respect of his premises; and

(*b*) he shall lay the supply pipe at his own expense, having first obtained, as respects any land not forming part of a street, the consent of the owners and occupiers thereof:

Provided that, where any part of the supply pipe is to be laid in a highway, he shall not himself break open the highway or lay that part of the pipe.

41.—(1) Upon receipt of such a notice as is referred to in the last foregoing section, the undertakers shall lay the necessary communication pipe and any part of the supply pipe which is to be laid in a highway and shall connect the communication pipe with the supply pipe:

Provided that where any part of the supply pipe is to be laid in a highway, they may elect to lay a main in the highway for such distance as they think fit in lieu of a supply pipe, and in that case shall lay a communication pipe from that main and connect it with the supply pipe.

(2) If the undertakers fail to carry out the said work within fourteen days after the person by whom the notice was given has laid a supply pipe in accordance with the provisions of the last foregoing section, they shall, unless they show that the failure was due to unavoidable accident or other unavoidable cause, be liable to a fine not exceeding £5 and to a further fine not exceeding 40*s*. for each day on which the default continues after the expiration of the said fourteen days.

(3) The expenses reasonably incurred by the undertakers in executing the work which they are required or authorized by this section to execute shall be repaid to them by the person by whom the notice was given and may be recovered by them from him summarily as a civil debt:

Provided that, if under the provisions of this section, the undertakers lay a main in lieu of part of a supply pipe, the additional cost incurred in laying a main instead of a supply pipe shall be borne by them.

(4) Notwithstanding anything in the foregoing provisions of this section, undertakers to whom such a notice as aforesaid is given may, within seven days after the receipt thereof, require the person giving the notice either to pay to them in advance the cost of the work, as estimated by their engineer, or to give security for payment thereof

to their satisfaction, and, where they make such a requirement, the period of fourteen days referred to in subsection (2) of this section shall not commence to run until the requirement has been complied with.

If any payment so made to the undertakers exceeds the expenses which under the foregoing provisions of this section they would be entitled to recover from the person giving the notice, the excess shall be repaid by them and, if and so far as those expenses are not covered by the payment, they may recover the balance from him summarily as a civil debt.

42.—(1) Subject to the provisions of this section, the undertakers may require the provision of a separate service pipe for each house or other building supplied, or to be supplied, by them with water.

(2) If, in the case of a house or other building already supplied with water but not having a separate service pipe, the undertakers give notice to the owner of the house or building requiring the provision of such a pipe, the owner shall within three months lay so much of the required pipe as will constitute a supply pipe and is not required to be laid in a highway, and the undertakers shall, within fourteen days after he has done so, lay so much of the required pipe as will constitute a communication pipe or a supply pipe to be laid in a highway and make all necessary connections.

(3) If an owner upon whom a notice has been served under the last foregoing subsection fails to comply therewith, the undertakers may themselves execute the work which he was required to execute.

(4) The expenses reasonably incurred by the undertakers in executing the work which they are required by subsection (2) of this section to execute, or which they are empowered by the last foregoing subsection to execute, shall be repaid to them by the owner of the house or building and may be recovered by them from him summarily as a civil debt, but without prejudice to the rights and obligations, as between themselves, of the owner and the occupier of the house or building.

(5) If the undertakers make default in executing the work which they are required by subsection (2) of this section to execute, they shall be liable to a fine not exceeding £5 and to a further fine not exceeding 40*s*. for each day on which the default continues after the expiration of the said fourteen days.

(6) For the purposes of the foregoing provisions of this section, two or more buildings in the same occupation and forming part of the same hereditament for rating purposes shall be treated as a single building.

(7) Where the owner of a group or block of houses is liable by law or undertakes in writing to pay the water rates in respect of all those houses, then, so long as he punctually pays those rates and the supply pipe of those houses is sufficient to meet the requirements thereof, the undertakers shall not require the provision of separate service pipes for those houses.

(8) Without prejudice to the provisions of the last foregoing subsection, where, on the coming into force of this section, two or more houses were being supplied with water by a single service pipe, the undertakers shall not require the provision of separate service pipes for those houses until either

(*a*) the existing supply pipe becomes so defective as to require renewal, or is no longer sufficient to

meet the requirements of the houses; or

(*b*) an installment of the water rate in respect of any of the houses remains unpaid after the end of the period for which it is due; or

(*c*) the houses are, by structural alterations to one or more of them, converted into a larger number of houses.

43. Where any premises which are within the limits of supply abut on, or are situate near to, any street which is, as to the whole or a part of its width, outside those limits, the undertakers may, for the purpose of supplying water to the owner or occupier of those premises, exercise with respect to the whole width of the street the like powers of laying, inspecting, repairing, altering, renewing and removing service pipes with any necessary stopcocks and fittings and of breaking open the street for that purpose as are exerciseable by them with respect to streets within the said limits, subject, however, to the like conditions and obligations.

44.—(1) All communication pipes, whether laid before or after the coming into force of this section, shall vest in the undertakers and the undertakers shall at their own expense carry out any necessary works of maintenance, repair or renewal of such pipes and any work on their mains incidental thereto.

(2) The undertakers shall also carry out any such necessary works as aforesaid in the case of so much of any supply pipe as is laid in a highway, and may recover the expenses reasonably incurred by them in so doing summarily as a civil debt from the owner of the premises supplied by the pipe, but without prejudice to the rights and obligations, as between themselves, of the owner and the occupier of the premises.

(3) If the undertakers fail to carry out any such necessary work with all reasonable despatch after service upon them of complaint of a defect from an owner or occupier of premises affected, they shall be liable to a fine not exceeding £5 and to a further fine not exceeding 40*s*. for each day on which the default continues.

Part XI—Stopcocks

45.—(1) On every service pipe laid after the coming into force of this section the undertakers shall, and on every service pipe laid before that date the undertakers may, fit a stopcock enclosed in a covered box, or pit, of such size as may be reasonably necessary.

(2) Every stopcock fitted on a service pipe after the coming into force of this section shall be placed in such position as the undertakers deem most convenient:

Provided that

(*a*) a stopcock in private premises shall be placed as near as is reasonably practicable to the street from which the service pipe enters those premises; and

(*b*) a stopcock in a street shall, after consultation with the highway authority concerned, be placed as near to the boundary thereof as is reasonably practicable.

Part XII—Water Rates and Charges *

46.—(1) Undertakers who supply water to any premises for domestic purposes may charge in respect thereof a water rate, which shall be calculated at a rate-poundage not exceeding the prescribed rate-poundage

(*a*) in the case of a house or of any premises not used solely for

* The determination of water rates in England is discussed by Leonard W. F. Millis, Secretary of the British Waterworks Association, on page 129 following.

business, trade or manufacturing purposes or for the exercise of functions by any public authority, on the net annual value thereof; and

(*b*) in the case of any other premises, on such proportion of the net annual-value thereof as may be prescribed or, if no proportion is prescribed, as may be determined by the Minister:

Provided that the undertakers may in any case make in respect of the supply such minimum charge as may be prescribed or, if no minimum charge is prescribed, 15*s*. per annum.

(2) For the purposes of this part of this schedule, where water supplied to a house within the curtilage of a factory is used solely for the domestic purposes of occupants of the house, the house shall be deemed separate premises not forming part of the factory.

(3) For the purposes of this part of this schedule, the net annual value of any premises shall be taken to be that value as appearing in the valuation list in force on the first day of the period of twelve months covered by the rate:

Provided that, if that value does not appear therein, or if the water rate is chargeable on a part only of any hereditament entered therein, the net annual value of the premises supplied shall be taken to be such sum, or, as the case may be, such fairly apportioned part of the net annual value of the whole hereditament, as, in default of agreement, may be determined by a court of summary jurisdiction.

(4) Subject to the provisions of subsection (2) of this section, where there is communication, otherwise than by a highway, between buildings or parts of buildings in the occupation of the same person, those buildings or parts of buildings shall, if the undertakers so decide, be treated, for the purpose of charging water rates, as one building having a net annual value equal to the aggregate of their net annual values:

Provided that a person aggrieved by a decision of the undertakers under this subsection may appeal to a court of summary jurisdiction.

47.—(1) The undertakers, in lieu of charging a water rate, may agree with any person requiring a supply of water for domestic purposes to furnish the supply, whether by meter or otherwise, on such terms and conditions as may be agreed.

(2) Charges payable under this section (including charges for any meter supplied by the undertakers) shall be recoverable in the manner in which water rates are recoverable.

48.—(1) Where water which the undertakers supply for domestic purposes, and in respect of which they charge a water rate

(*a*) is used for watering a garden; or

(*b*) is used for horses, washing vehicles, or other purposes, in stables, garages or other premises where horses or vehicles are kept,

the undertakers may in either case, if a hosepipe or other similar apparatus is used, charge in respect of that use of the water an additional annual sum not exceeding the prescribed sum or, if no sum is prescribed, such sum as the Minister may determine.

(2) Where in either of such cases the water used is drawn from a tap outside a house, but no hosepipe or similar apparatus is used, the undertakers may charge an additional annual sum not exceeding one-half the maximum sum chargeable under the last foregoing subsection.

(3) Sums charged under the provisions of this section shall be paid in advance either quarterly or half-yearly,

as the undertakers may determine, and shall be recoverable in the manner in which water rates are recoverable.

49.—(1) The following provisions of this section shall have effect where a maximum charge for a supply of water by meter is prescribed.

(2) The undertakers shall not be bound to supply with water otherwise than by meter

(*a*) any premises used as a house whereof a part is used by the same occupier for any business, trade or manufacturing purpose for which water is required or any premises used as a farmhouse;

(*b*) any public institution, hospital, mental institution, nursing home, sanatorium, school, club, hostel, assembly hall, place of public entertainment, hotel, restaurant or licensed premises, within the meaning of that expression as used in the Licensing (Consolidation) Act, 1910;

(*c*) any boarding-house capable of accommodating twelve or more persons including the persons usually resident therein; or

(*d*) any premises which are used solely for business, trade or manufacturing purposes and in which a supply of water for domestic purposes only is required.

(3) In any of the cases mentioned in the last foregoing subsection the water shall be supplied at a charge not exceeding the prescribed charge, subject, however, to a minimum annual charge equal to the annual amount which would be payable by way of water rate for a supply of water for domestic purposes furnished to the premises in question.

50. Where a person who takes a supply of water for domestic purposes from the undertakers otherwise than by meter desires to use any of the water so supplied

(*a*) for operating a water-cooled refrigerating apparatus; or

(*b*) for operating any apparatus depending while in use upon a supply of continuously running water, not being an apparatus used solely for heating the water; or

(*c*) for cleaning, regenerating or supplying motive power to any apparatus used for softening water,

the undertakers may, subject as hereinafter provided, require that all water so used shall

(i) if a charge for a supply of water by meter is prescribed, be taken by meter at a charge not exceeding the prescribed charge; or

(ii) whether such a charge is prescribed or not, be paid for at a reasonable rate to be determined, in default of agreement, by a court of summary jurisdiction:

Provided that no charge shall be made under this section in respect of a water softening apparatus used within a house for which the supply of water is taken, if one such apparatus only is used and if the water softened thereby is used solely for domestic purposes.

51. Where water which the undertakers supply for domestic purposes and in respect of which they charge a water rate is used by means of a hosepipe, or other similar apparatus, for watering a garden, or for horses, washing vehicles, or other purposes in stables, garages or other premises where horses or vehicles are kept, and the consumer takes also a supply of water by meter for purposes other than domestic, the undertakers may require that all water used by him by means of the hosepipe or other apparatus shall be taken by meter and paid for at the rate for the time being applicable to his supply by meter for non-domestic purposes.

52.—(1) No person shall be entitled to demand, or to continue to receive, from the undertakers a supply of water to any habitation to which this section applies unless he has

(*a*) agreed with the undertakers to take a supply of water by meter and to pay to them such minimum annual sum as will give them a reasonable return on the capital expenditure incurred by them in providing the required supply, and will cover other standing charges incurred by them in order to meet the possible maximum demand for his habitation, and will yield a reasonable return on the cost of the water supplied; and

(*b*) secured to the reasonable satisfaction of the undertakers, by way of deposit or otherwise, payment of such a sum as may be reasonable having regard to his possible maximum demand for water.

The annual sum to be so paid and the security to be so given shall be determined, in default of agreement, by a court of summary jurisdiction, whose decision shall be final.

(2) The habitations to which this section applies are tents, vans or other conveyances, whether on wheels or not, and sheds or similar structures, not being structures to which the building by-laws of the local authority of the district apply.

53. Where two or more houses or other buildings in the occupation of different persons are supplied with water by a common pipe, the owner or occupier of each of them shall be liable to pay the same water rate for the supply as he would have been liable to pay if it had been supplied with water by a separate pipe.

54.—(1) Where a house or other building supplied with water by the undertakers has a net annual value not exceeding £13, the owner instead of the occupier shall, if the undertakers so resolve, pay the rate for the supply of water:

Provided that in the administrative county of London £20 shall be deemed to be substituted in this section for £13 and in any area in which a higher limit of value than £13 is in force for the purposes of the proviso to subsection (1) of Sec. 11 of the Rating and Valuation Act, 1925, that higher limit shall be deemed to be substituted in this section for £13.

(2) An owner of premises to which a resolution of undertakers under this section applies shall, if he pays the amount due by him in respect of a water rate before the expiration of one-half of the period in respect of which the rate or installment of the rate is payable, or before such later date as may be specified by the undertakers, be entitled to an allowance calculated at the rate of 5 per cent.

55.—(1) Undertakers who charge water rates under the special act shall make such a rate by fixing, in respect of a period of twelve months commencing on either the first day of January, the first day of April, the first day of July or the first day of October, the rate-poundage or, as the case may be, the scale of rate-poundages, by reference to which amounts due under the rate are to be calculated and, subject to the provisions of this section, any such rate shall be payable in advance by equal quarterly installments on those dates, or, if the undertakers so resolve, by equal half-yearly installments on that one of those dates which is the first day of the rate period and on the first day of the seventh month comprised in that period.

(2) A water rate under this section, or in force under any enactments re-

lating to the undertakers immediately before the coming into operation of this section, shall, unless and until a new rate is made, continue to operate in respect of each successive period of twelve months.

(3) If, and so long as, the water rates are payable in advance by half-yearly installments

(*a*) no proceedings shall be commenced for the recovery of any such installment until the expiration of two months from the first day of the half-year in respect of which it has been demanded; and

(*b*) if the person who is, or who, but for the provision of the last foregoing section, would be, liable to pay the water rate payable in respect of any premises is in occupation of those premises during a portion only of a half-year, he, or, as the case may be, the owner of the premises, shall be liable to pay so much only of the half-yearly installment as bears to the whole installment the same proportion as the number of days within the half-year during which the first-mentioned person is in occupation bears to the number of days in the half-year, and, if any greater proportion of installment has been paid, the person by whom it was paid shall be entitled to recover the excess from the undertakers, except in so far as he has previously recovered it from an incoming occupier:

Provided that nothing in this paragraph shall exempt the owner of any premises from liability in respect of any subsequent portion of the half-year during which the premises may again become occupied.

(4) Subject to the provisions of the last foregoing subsection

(*a*) where the undertakers commence to give a supply of water to any premises, either for the first time or after a discontinuance of supply, the then current installment of the water rate shall become payable on the day on which notice requiring the supply is given to the undertakers or, if no such notice is given, on the day when they commence to give the supply; and

(*b*) the liability of a person to pay an installment of a water rate shall not be affected by the fact that, before the end of the period in respect of which the installment became payable by him, he or his tenant, as the case may be, removes from the premises in question, or causes the supply of water thereto to be discontinued.

(5) Nothing in this section affects any right of the undertakers to make a minimum charge in respect of water rates.

56.—(1) Where, in consequence of a proposal under Sec. 37 of the Rating and Valuation Act, 1925, an amendment is made in the valuation list for the time being in force, or in consequence of a requisition under Sec. 47 of the Valuation (Metropolis) Act, 1869, a provisional list comes into operation, the amendment or provisional list shall for the purpose of calculating the amount due in respect of any water rate payable under the special act have effect retrospectively as from the date when the proposal or requisition was made and, notwithstanding anything in the last foregoing section with respect to the equality of installments of a water rate, any necessary adjustments shall be made in the then current installments of the rates and any subsequent installments thereof.

(2) If it is found that, by reason of the foregoing provisions, too much or too little has been paid in respect of any water rate, the difference shall be repaid or allowed or, as the case may be, shall be paid and may be recovered in the manner in which water rates are recoverable.

57.—(1) The undertakers may allow discounts or rebates in consideration of prompt payment of water rates and charges:

Provided that such discounts or rebates shall be at the same rate under like circumstances to all persons and shall not in any case exceed 5 per cent.

(2) If, and so long as, the undertakers allow such discounts or rebates, notice of the effect of this section shall be endorsed on every demand note for water rates and charges.

(3) This section shall not apply in any case where a discount is payable under Sec. 54 of this schedule.

58. If it is shown to the satisfaction of a justice of the peace on sworn information in writing that a person is quitting, or is about to quit, premises to which the undertakers supply water and has failed to pay on demand an installment of a water rate or charge payable by, and due from, him in respect of those premises, and intends to evade payment thereof by departing from the premises, the justice may, in addition to issuing a summons for nonpayment of the sum due, issue a warrant under his hand authorizing the person named therein forthwith to enter the premises and to seize sufficient goods and chattels of the defaulter to meet the claim of the undertakers and to detain them until the complaint is determined upon the return of the summons.

59.—(1) Where the undertakers supply water by meter, the register of the meter shall be prima facie evidence of the quantity of water consumed.

(2) Any question arising between the undertakers and a consumer with respect to the quantity of water consumed may, on the application of either party, be determined by a court of summary jurisdiction.

(3) If the meter on being tested is proved to register incorrectly to any degree exceeding 5 per cent

(*a*) the meter shall be deemed to have registered incorrectly to that degree since the last occasion but one before the date of the test on which a reading of the index of the meter was taken by the undertakers, unless it is proved to have begun to register incorrectly on some later date; and

(*b*) the amount of any refund to be made to, or of any extra payment to be made by, the consumer shall be paid or allowed by the undertakers or paid by the consumer, as the case may be, and in the case of an extra payment, shall be recoverable in the manner in which water rates are recoverable.

Part XIII—Provisions for Preventing Waste, etc., of Water, and as to Meters and Other Fittings

60.—(1) The undertakers may require that

(*a*) any building the supply of water to which need not under the special act be constantly laid on under pressure; and

(*b*) any house the erection of which was not commenced before the coming into force of this section and to which water is required to be

delivered at a height greater than 35 ft. below the draw-off level of the service reservoir from which a supply of water is being, or is to be, furnished by them,

shall be provided with a cistern having a ball and stopcock fitted on the pipe conveying water to it and, in the case of such a house as is mentioned in paragraph (*b*) of this subsection, may require that the cistern shall be capable of holding sufficient water to provide an adequate supply to the house for a period of 24 hours.

(2) If a consumer, whom the undertakers have in accordance with the foregoing provisions required to provide a cistern, fails to comply with the requirement, or if a consumer fails to keep in good repair any cistern in use in his building, or the ball and stopcock appurtenant to that cistern, the undertakers may themselves provide a cistern, or execute any repairs necessary to prevent waste of water, and may recover the expenses reasonably incurred by them in so doing summarily as a civil debt from the owner of the building, but without prejudice to the rights and obligations, as between themselves, of the owner and the consumer.

61. The undertakers may test any water fittings used in connection with water supplied by them.

62. An authorized officer of the undertakers may, between the hour of seven in the forenoon and one hour after sunset, on producing, if required, evidence of his authority, enter any premises supplied with water by the undertakers in order to examine if there be any waste or misuse of such water and, if, after production of his authority, he is refused admittance to the premises, or is obstructed in making his examination, the person refusing him admittance, or so obstructing him, shall be liable to a fine not exceeding £10.

63.—(1) If the undertakers have reason to think that some injury to or defect in a supply pipe which they are not under obligation to maintain is causing, or is likely to cause, waste of water or injury to person or property, they may execute such work as they think necessary or expedient in the circumstances of the case without being requested so to do and, if any injury to or defect in the pipe is discovered, the expenses reasonably incurred by the undertakers in discovering it and in executing repairs shall be recoverable by them summarily as a civil debt from the owner of the premises supplied, but without prejudice to the rights and obligations, as between themselves, of the owner and the occupier of the premises.

(2) Where several houses or other buildings in the occupation of different persons are supplied with water by one common supply pipe belonging to the owners or occupiers of the houses or buildings, the amount of any such expenses as aforesaid reasonably incurred from time to time by the undertakers in the maintenance and repair of that pipe may be recovered by them summarily as a civil debt from those owners or occupiers in such proportions as, in case of dispute, may be settled by the court.

64.—(1) If any person wilfully or negligently causes or suffers any water fitting which he is liable to maintain to

(*a*) be or remain so out of order, or so in need of repair; or

(*b*) be or remain so constructed or adapted, or be so used,

that the water supplied to him by the undertakers is, or is likely to be, wasted, misused or unduly consumed,

or contaminated before use, or that foul air or any impure matter is likely to return into any pipe belonging to, or connected with a pipe belonging to, the undertakers, he shall be liable to a fine not exceeding £5.

(2) If any water fitting which any person is liable to maintain is in such a condition, or so constructed or adapted as aforesaid, the undertakers, without prejudice to their right to institute proceedings under the last foregoing subsection, may require that person to carry out any necessary repairs or alterations, and, if he fails to do so within 48 hours, may themselves carry out the work and recover from him summarily as a civil debt the expenses reasonably incurred by them in so doing.

65.—(1) An owner or occupier of premises supplied with water by the undertakers who without their consent supplies any of that water to another person for use in other premises, or wilfully permits another person to take any of that water for use in other premises, shall (without prejudice to the right of the undertakers to recover from such owner or occupier the value of the water so supplied or permitted to be taken) be liable to a fine not exceeding £5, unless that other person requires the water for the purpose of extinguishing a fire, or is a person supplied with water by the undertakers but temporarily unable, through no default of his own, to obtain water.

(2) If a person wrongfully takes, uses or diverts water from a reservoir, watercourse, conduit, pipe or other apparatus belonging to the undertakers, or from a pipe leading to or from any such reservoir, watercourse, conduit, pipe or other apparatus, or from a cistern or other receptacle containing water belonging to the undertakers or supplied by them for the use of a consumer of water from them, he shall be liable to a fine not exceeding £5.

(3) Any person who, having from the undertakers a supply of water otherwise than by meter, uses any water so supplied to him for a purpose other than those for which he is entitled to use it shall be liable to a fine not exceeding 40*s*. without prejudice to the right of the undertakers to recover from him the value of the water misused.

66.—(1) If any person fraudulently alters the index of any meter used by the undertakers for measuring the water supplied by them, or prevents any such meter from registering correctly the quantity of water supplied, or fraudulently abstracts or uses water of the undertakers, he shall, without prejudice to any other right or remedy of the undertakers, be liable to a fine not exceeding £5, and the undertakers may do all such work as is necessary for securing the proper working of the meter, and may recover the expenses reasonably incurred by them in so doing from the offender summarily as a civil debt.

(2) For the purposes of this section, if it is proved that a consumer has altered the index of a meter, it shall rest upon him to prove that he did not alter it fraudulently, and the existence of any artificial means under the control of a consumer for preventing a meter from registering correctly, or for enabling him fraudulently to abstract or use water, shall be evidence that he has fraudulently prevented the meter from registering correctly or, as the case may be, has fraudulently abstracted or used water.

67. If any person either

(*a*) wilfully and without the consent of the undertakers; or

(*b*) negligently

turns on, opens, closes, shuts off or otherwise interferes with any valve, cock or other work or apparatus belonging to the undertakers and thereby causes the supply of water to be interfered with, he shall be liable to a fine not exceeding £5 and, whether proceedings be taken against him in respect of his offense or not, the undertakers may recover from him summarily as a civil debt the amount of any damage sustained by them:

Provided that this section shall not apply to a consumer closing the stopcock fixed on the service pipe supplying his premises, so long as he has obtained the consent of any other consumer whose supply will be affected thereby.

68.—(1) Any person who without the consent of the undertakers attaches any pipe or apparatus to a pipe belonging to the undertakers, or to a supply pipe, or makes any alteration in a supply pipe or in any apparatus attached to a supply pipe, shall be liable to a fine not exceeding £5, and any person who uses any pipe or apparatus which has been so attached, or altered, shall be liable to the same penalty unless he proves that he did not know, and had no grounds for suspecting, that it had been so attached or altered.

(2) When an offense under this section has been committed, then, whether proceedings be taken against the offender in respect of his offense or not, the undertakers may recover from him summarily as a civil debt the amount of any damage sustained by them and the value of any water wasted, misused or improperly consumed.

69.—(1) A consumer who has not obtained the consent of the undertakers shall not connect or disconnect any meter by means of which water supplied by the undertakers is intended to be, or has been, measured for the purposes of the payment to be made to them, but, if he requires such a meter to be connected or disconnected, shall give to the undertakers not less than 24 hours' notice of his requirements and of the time when the work can be commenced and, thereupon, the undertakers shall carry out the necessary work and may recover from him summarily as a civil debt the expenses reasonably incurred by them in so doing.

(2) A consumer who contravenes any of the provisions of this section, and undertakers who fail to carry out with all reasonable dispatch any such work as aforesaid, shall be liable to a fine not exceeding 40*s*.

70. Subject to the provisions of the special act with respect to the breaking open of streets, the undertakers may for the purpose of measuring the quantity of water supplied, or preventing and detecting waste, affix and maintain meters and other apparatus on their mains and service pipes and may insert in any street, but as near as is reasonably practicable to the boundary thereof, the necessary covers or boxes for giving access and protection thereto, and may for that purpose temporarily obstruct, break open, and interfere with streets, tramways, sewers, pipes, wires and apparatus:

Provided that the undertakers shall not under the powers of this section interfere with

(*a*) any telegraphic line belonging to or used by the Postmaster General, except in accordance with, and subject to, the provisions of the Telegraph Act, 1878; or

(*b*) any works or apparatus of any electricity undertakers, except in accordance with the provisions of Sec. 15 of the Electric Lighting Act, 1882, or Sec. 17 of the Schedule to

the Electric Lighting (Clauses) Act, 1899; or

(*c*) any pipes or apparatus of any gas undertakers, except under the supervision (if given) of an authorized officer of those undertakers and in accordance with plans approved by them or by such officer, or, in case of any difference, by a court of summary jurisdiction.

Part XIV—Pollution of Water by Manufacture, etc., of Gas

71.—(1) Any person manufacturing or supplying gas who

(*a*) causes or suffers any washing or other liquid produced in, or resulting from, the manufacture or supply of gas, or the treatment of any residual products of the manufacture of gas, to run or to be conducted

(i) into, or into any drain communicating with any spring, stream, reservoir, aqueduct or other water works belonging to the undertakers; or

(ii) into any depression in the ground or excavation in such proximity to any spring, well or adit belonging to any such undertakers that contamination of water therein is reasonably probable; or

(*b*) wilfully does any other act connected with the manufacture or supply of gas, or the treatment of any such residual products as aforesaid, whereby any water of the undertakers is fouled,

shall be liable

(*a*) on summary conviction, to a fine not exceeding £50 and to a further fine not exceeding £10 for each day during which his offense continues after the expiration of 24 hours from the service on him by the undertakers of notice of his offense; or

(*b*) on conviction on indictment, to a fine not exceeding £200 and to a further fine not exceeding £20 for each such day as aforesaid.

72. If water belonging to the undertakers is fouled by gas belonging to any person manufacturing or supplying gas, he shall be liable to a fine not exceeding £20, and to a further fine not exceeding £10 for each day during which his offense continues after the expiration of 24 hours from the service on him by the undertakers of notice of his offense.

73.—(1) For the purpose of ascertaining whether water belonging to them is being fouled by gas belonging to any person manufacturing or supplying gas, the undertakers may open the ground, and examine the pipes and other works of that person:

Provided that, before proceeding so to do, they shall give 24 hours' notice of the time at which the examination is intended to take place both to that person and also to the persons having the control or management of the street or other place where they propose to open the ground, and shall be subject to the like obligations and liable to the same penalties in relation to reinstatement, maintenance and other matters as those to which they are subject and liable when breaking open streets for the purpose of laying water pipes.

(2) If, upon such examination as aforesaid, it appears that water of the undertakers has been fouled by gas belonging to the said manufacturer or supplier of gas, the undertakers may recover from him summarily as a civil debt the expenses reasonably incurred by them in connection with the examination and the repair of the street or place disturbed in the examination,

but otherwise the undertakers shall pay all expenses of the examination and repair, and shall also make good to the said person any injury which may be occasioned to his pipes or other works by the examination.

The amount of the expenses of any such examination and repair, and of any injury so occasioned, shall, in default of agreement, be referred to arbitration.

Part XV—Financial Provisions Applicable to Water Companies

74.—(1) Subject to the provisions of this section, where the undertakers are a company, they shall not in respect of any year pay dividends on the paid-up capital of their undertaking at rates per cent greater than the following rates, that is to say:

(*a*) on capital subscribed before the date on which this section comes into force, the rates which they were entitled to pay thereon immediately before that date; and

(*b*) on capital subscribed after that date, 5 per cent or, in the case of such capital entitled by the terms of subscription to a rate of dividend lower than 5 per cent, that lower rate.

(2) Nothing in the last foregoing subsection shall prevent the payment of a greater dividend in order to make up deficiencies in previous dividends:

Provided that, as respects capital subscribed after the date on which this section comes into force, this subsection shall apply only in relation to deficiencies arising during the last five years before the year in respect of which a dividend is being paid.

(3) Paragraph (1) of subsection (1) of Sec. 1 of the Trustee Act, 1925 (which includes among trustee stocks any debenture, guarantee or preference stocks of water undertakers, being a company incorporated by special act of Parliament or by Royal Charter, if for the previous ten years the company has paid a dividend of not less than 5 per cent on its ordinary stock) shall apply in a case where the undertakers are incorporated by statutory order as well as in a case where they are such a company as is referred to in that paragraph, and shall have effect, in any case to which the paragraph as extended by this subsection applies, as if for the words "5 per cent" there were substituted the words "4 per cent."

75.—(1) Where the undertakers are a company, all ordinary and preference stock issued by them shall be issued in accordance with the following provisions of this section.

(2) All stock issued by the undertakers shall be offered for sale by public auction or tender in such manner, at such times and subject to such conditions of sale as the undertakers from time to time determine:

Provided that

(*a*) notice of the intended sale shall be given in writing to the local authority of every district wholly or partly within their limits of supply and to the secretary of the London Stock Exchange at least seven days before the day of auction or the last day for the reception of tenders, as the case may be, and shall be advertised once in each of two successive weeks in one or more local newspapers circulating within the limits of supply;

(*b*) a reserve price shall be fixed and notice thereof shall be sent by the undertakers in a sealed letter to be received by the Minister not less than 24 hours before, but not to be opened until after, the day of auc-

tion or the last day for the receipt of tenders, as the case may be;

(*c*) in the case of a sale by auction, no lot offered for sale shall comprise stock of greater nominal value than £100;

(*d*) in the case of a sale by tender, no preference shall be given to one of two or more persons tendering the same sum, except that the offer by tender of any holder of stock of the undertakers may be accepted in preference to the offer of the same sum by any person who is not such a holder as aforesaid and preference may in like manner be given to the offer of any employee of the undertakers or consumer of water supplied by the undertakers;

(*e*) in the case of a sale by auction a bid (other than a first bid) shall not be recognized unless it is in advance of the last preceding bid; and

(*f*) it shall be one of the conditions of sale that the total sum payable by the purchaser shall be paid to the undertakers within three months after the date of the auction or of the acceptance of the tender, as the case may be.

(3) Any stock which has been offered for sale in accordance with the last foregoing subsection and is not sold may be disposed of at such price and in such manner as the undertakers may determine for the purpose of realizing the best price obtainable.

(4) As soon as possible after the conclusion of the sale or sales, the undertakers shall send a report thereof to the Minister stating the total amount of each class of stock sold, the total amount obtained as premium (if any) and the highest and lowest prices obtained for each class of stock.

76.—(1) Where the undertakers are a company, they may, subject to the provisions of this section, by setting apart in any year out of revenue such sums as they think fit, form and maintain

(*a*) a reserve fund, for the purpose of making good any deficiency which may at any time occur in the amount of divisible profits, or of meeting any extraordinary claim or demand which may at any time be made upon them;

(*b*) a contingency fund, for the purpose of meeting contingencies, or defraying the cost of renewing, repairing, enlarging or improving any part of the works forming part of the undertaking.

(2) Any sums so set apart for the formation or maintenance of a reserve or contingency fund may from time to time be invested in securities in which trustees are authorized to invest trust moneys, and, subject to the provisions of the next but one succeeding subsection, the dividends and interest arising from such securities may also be invested in the same or like securities so as to accumulate at compound interest for the credit of the fund in question.

(3) The undertakers shall transfer to any reserve fund or contingency fund formed under the foregoing provisions of this section any sum then standing to the credit of any existing reserve fund or contingency fund, as the case may be.

(4) Whenever, and so long as, the aggregate amount standing to the credit of the reserve fund and contingency fund together amounts to (or, by reason of such a transfer as aforesaid, exceeds) a sum equal to 12.5 per cent of the capital expenditure theretofore incurred by the undertakers for the pur-

poses of their undertaking, no contribution from the revenue of the undertaking shall be made to either of the funds, and the interest and dividends on the funds shall not be invested but shall be treated as income of the undertaking.

(5) The aggregate amount which, subject to the provisions of the last foregoing subsection, may be carried by the undertakers in any year to the formation or maintenance of the reserve fund and contingency fund shall not exceed a sum equal to 1.25 per cent of the capital expenditure theretofore incurred by the undertakers for the purposes of their undertaking.

77.—(1) Where the undertakers are a company, it shall not be lawful for them to carry forward at the end of any year to the credit of the profit and loss (net revenue) account any sum exceeding the total of the following amounts, that is to say:

(*a*) the amount required for paying any dividend or interest which they are entitled, or required, to pay, but have not paid, in respect of that year;

(*b*) an amount equal to the total sum which they will be required to pay during the next following year as interest on any mortgages or debenture stock; and

(*c*) an amount equal to the total sum which they might lawfully distribute as dividends on the preference and ordinary capital of the undertaking in respect of the next following year.

(2) Any sum which, but for the provisions of this section, might at the end of any year have been so carried forward as aforesaid shall be applied towards the reduction of water rates and charges in future years.

78.—(1) Where the undertakers are a company, they may

(*a*) grant gratuities, pensions or superannuation allowances to, or to the widows, families or dependants of, their employees;

(*b*) establish contributory superannuation schemes, and establish and contribute to superannuation funds for the benefit of their employees;

(*c*) enter into and carry into effect agreements with any insurance company or other association or company for securing to any such employee, widow, family or dependent such gratuities, pensions or allowances as are by this section authorized to be granted;

(*d*) give donations or subscriptions to charitable institutions, sick funds, benevolent funds and other objects calculated to benefit their employees;

(*e*) subscribe to the funds of any association formed for the purpose of furthering the interests of water undertakers;

(*f*) make contributions for furthering research in matters with which water undertakers and their officers are concerned.

(2) No employee of the undertakers shall be required to become a contributor to any superannuation fund established under this section until the fund has been registered under the Superannuation and other Trust Funds (Validation) Act, 1927.

Part XVI—General and Miscellaneous

79. A consumer who wishes the supply of water to his premises to be discontinued shall give not less than 24 hours' notice to the undertakers.

80. The undertakers, before commencing to execute repairs or other work which will cause any material interference with the supply of water, shall, except in a case of emergency, give to all consumers likely to be affected such notice as is reasonably practicable and shall complete the work with all reasonable despatch.

81.—(1) The rating authority of any area within which the undertakers supply water shall on application furnish to the undertakers a copy of their current valuation list, or of such part thereof or such entries therein as may be specified in the application, and their clerk shall, upon request, certify any such copy in accordance with the provisions of Sec. 43 of the Rating and Valuation Act, 1925.

(2) In respect of every such copy the rating authority may demand a sum not exceeding 5*s.* for every hundred entries numbered separately, and for the purposes of this subsection any number of entries less than a complete hundred shall be treated as a complete hundred.

82.—(1) Subject to the provisions of this section, any authorized officer of the undertakers shall, on producing, if so required, some duly authenticated document showing his authority, have a right to enter any premises at all reasonable hours

(*a*) for the purpose of inspecting and examining meters used by the undertakers for measuring the water supplied by them, and of ascertaining therefrom the quantity of water consumed;

(*b*) for the purpose of ascertaining whether there is, or has been, on or in connection with the premises any contravention of the provisions of the special act or of any by-laws made thereunder;

(*c*) for the purpose of ascertaining whether or not circumstances exist which would authorize the undertakers to take any action, or execute any work, under the special act or any such by-laws;

(*d*) for the purpose of taking any action, or executing any work, authorized or required by the special act or any such by-laws to be taken, or executed, by the undertakers:

Provided that admission to any premises shall not be demanded as of right unless 24 hours' notice of the intended entry has been given to the occupier.

(2) If it is shown to the satisfaction of a justice of the peace on sworn information in writing

(*a*) that admission to any premises has been refused, or that refusal is apprehended, or that the premises are unoccupied or that the occupier is temporarily absent, or that the case is one of urgency, or that an application for admission would defeat the object of the entry; and

(*b*) that there is reasonable ground for entry into the premises for any such purpose as aforesaid,

the justice may by warrant under his hand authorize the undertakers by any authorized officer to enter the premises, if need be by force:

Provided that such a warrant shall not be issued unless the justice is satisfied either that notice of the intention to apply for a warrant has been given to the occupier, or that the premises are unoccupied, or that the occupier is temporarily absent, or that the case is one of urgency, or that the giving of such notice would defeat the object of the entry.

(3) An authorized officer entering any premises by virtue of this section, or of a warrant issued thereunder, may

take with him such other persons as may be necessary, and on leaving any unoccupied premises which he has entered by virtue of such a warrant shall leave them as effectually secured against trespassers as he found them.

(4) Every warrant granted under this section shall continue in force until the purpose for which the entry is necessary has been satisfied.

(5) If any person who in compliance with the provisions of this section, or of a warrant issued thereunder, is admitted into a factory or workplace discloses to any person any information obtained by him in the factory or workplace with regard to any manufacturing process or trade secret, he shall, unless such disclosure was made in the performance of his duty, be liable to a fine not exceeding £100, or to imprisonment for a term not exceeding three months.

(6) Nothing in this section shall be construed as limiting the power of entry conferred in Part XIII of this schedule for the purpose of making examination as to waste or misuse of water.

83. A person who wilfully obstructs any person acting in the execution of the special act, or of any by-law or warrant made or issued thereunder, shall be liable to a fine not exceeding £5 and to a further fine not exceeding £5 for each day on which the offense continues after conviction therefor.

84. If, on a complaint made by the owner of any premises, it appears to a court of summary jurisdiction that the occupier of those premises prevents the owner from executing any work which he is by, or under, the special act required to execute, the court may order the occupier to permit the execution of the work.

85. Save as otherwise expressly provided, all offenses and fines under the special act may be prosecuted and recovered under the Summary Jurisdiction Acts.

86. Where provision is made by, or under, the special act for the imposition of a daily penalty in respect of a continuing offense, the court by which a person is convicted of the original offense may fix a reasonable period from the date of conviction for compliance by the defendant with any directions given by the court and, where a court has fixed such a period, the daily penalty shall not be recoverable in respect of any day before the expiration thereof.

87. Proceedings in respect of an offense created by, or under, the special act shall not, without the written consent of the Attorney General, be taken by any person other than the undertakers or a person aggrieved.

88. Where two or more sums are claimed from any person as being due under the special act, or under by-laws made thereunder, a complaint, summons or warrant may contain in the body thereof, or in a schedule thereto, all or any of the sums so claimed.

89.—(1) Where any enactment in the special act provides

(*a*) for an appeal to a court of summary jurisdiction against a requirement, refusal or other decision of the undertakers; or

(*b*) for any matter to be determined by, or an application in respect of any matter to be made to, a court of summary jurisdiction,

the procedure shall be by way of complaint for an order, and the Summary Jurisdiction Acts shall apply to the proceedings.

(2) The time within which any such appeal may be brought shall be 21 days from the date on which notice of the undertakers' requirement, refusal or other decision was served upon the person desiring to appeal, and for the purposes of this subsection the making of the complaint shall be deemed to be the bringing of the appeal.

(3) In any case where such an appeal lies, the document notifying to the person concerned the decision of the undertakers in the matter shall state the right of appeal to a court of summary jurisdiction and the time within which such an appeal may be brought.

90. Where a person aggrieved by any order, determination or other decision of a court of summary jurisdiction under the special act is not by any other enactment authorized to appeal to a court of quarter sessions, he may, subject to any express provisions in the special act to the contrary, appeal to such a court.

91. In arbitrations under the special act the reference shall, except where otherwise expressly provided, be to a single arbitrator to be appointed by agreement between the parties or, in default of agreement, by the Minister.

92. In any case where no express provision with respect to compensation is made by the special act, the undertakers shall pay to the owners and occupiers of, and all other persons interested in, any lands or streams taken or used for the purposes of that act, or injuriously affected by the construction or maintenance of the works thereby authorized or otherwise by the execution of the powers thereby conferred, compensation for the value of the lands or streams so taken or used and for all damage sustained by those owners, occupiers and other persons by reason of the exercise as to those lands and streams of the powers conferred on the undertakers by the special act, or any act incorporated therewith.

The amount of such compensation shall, in case of dispute, be settled in manner provided by the Lands Clauses Acts with reference to the taking of lands otherwise than by agreement.

93.—(1) Subject to the provisions of this section and to any provisions of the special act empowering the undertakers to execute works specified therein, or to abstract water, nothing in the special act shall authorize the undertakers without the consent of the navigation authority concerned

(*a*) to interfere with any river, canal, dock, harbor, basin, lock or reservoir so as injuriously to affect navigation thereon or the use thereof or the access thereto, or to interfere with any towing path, so as to interrupt the traffic thereon;

(*b*) to interfere with any bridge crossing any river, canal, dock, harbor or basin;

(*c*) to execute any works in, across or under any dock, harbor, basin, wharf, quay or lock, or any land which belongs to a navigation authority and is held or used by them for the purposes of their undertaking;

(*d*) to execute any works which will interfere with the improvement of, or the access to, any river, canal, dock, harbor, basin, lock, reservoir, or towing path, or with any works appurtenant thereto or any land necessary for the enjoyment or improvement thereof;

or without the consent of the catchment board to execute any works which will interfere with the exercise by a

catchment board of their functions under any enactment, or without the consent of the railway company concerned, to execute any works along, across or under any railway of a railway company:

Provided that consent under this section shall not be unreasonably withheld, and if any question arises as to whether or not consent is unreasonably withheld, either party may require that it shall be referred to an arbitrator to be appointed, in default of agreement, by the President of the Institution of Civil Engineers.

(2) Upon an arbitration under this section, the arbitrator shall determine

(*a*) whether any works which the undertakers propose to execute are such works as under the last foregoing subsection they are not entitled to execute without consent; and

(*b*) if they are such works, whether the injury, if any, to the navigation authority, catchment board or railway company will be of such a nature as to admit of being fully compensated by money; and

(*c*) if the works are of such a nature, the conditions, including conditions of a financial character with respect to the payment of compensation, future liabilities and otherwise, subject to which

(i) the navigation authority, catchment board or railway company shall, if they so elect, carry out the works on behalf of the undertakers; or

(ii) in default of such election, the undertakers may themselves carry out the works.

If the arbitrator should determine that the proposed works are such works as the undertakers are not entitled to execute without consent and that the works would cause injury to the navigation authority, catchment board or railway company of such a nature as not to admit of being fully compensated by money, the undertakers shall not proceed to execute the works, but in any other case they may execute the works subject to compliance with such conditions, including the payment of such compensation, as the arbitrator may have determined.

(3) For the purposes of this section, a navigation authority shall be deemed to be concerned with any river, canal, dock, harbor, basin, lock, reservoir, towing path, wharf, quay or land if it belongs to them and forms part of their undertaking, or if they have statutory rights of navigating on or using it, or of demanding tolls or dues in respect of navigation thereon or the use thereof.

(4) Nothing in this section shall be construed as limiting the powers of the undertakers under the special act in respect of the opening and breaking up of streets and bridges.

94.—(1) The undertakers shall, at all times after the expiration of six months from the date on which the special act was passed or made, keep at their principal office a copy thereof printed by the printers to His Majesty, and shall also within the said six months deposit such a copy with the clerk of the council of every county and town clerk of every county borough within which they supply, or propose to supply, water, or have, or propose to construct, any water works.

(2) If the undertakers fail to comply with any of the provisions of this section, they shall be liable to a fine not exceeding £20 and to a further fine not exceeding £5 for each day during which such a copy is not so kept or has not been so deposited.

British Water Rate Practice

The traditional British method of collection of charges for water service is somewhat comparable to the old "flat rate" system in the United States. American flat rates, it will be remembered, were based upon the number of rooms in a residence as well as the number of fixtures of one type or another which the property had available for use of water.

A communication has been received from Leonard W. F. Millis, Secretary of the British Waterworks Association, which outlines the basis of assessment of water rates in the British Isles. Excerpts from it follow:

It is not an easy matter to explain the basis of water rates or even the basis of general rating operating in this country. I am not aware of the system of central and local taxation in America and I expect that in your country you, as I do, get so accustomed to the national and local systems that you find it not very easy to explain to people who have not been brought up with them.

Essentially taxation in this country is divided into:

1. National taxation
2. Local taxation

For water works purposes we are not concerned with national taxation, but with local taxation, and then only indirectly. I should add that local taxation which has to cover a large number of local services is often state-aided, particularly for those services which are of more than local importance; for example, education and police.

Local taxation is based upon the old Elizabethan Poor Law Act of 1601, when the parishes were required to make provision for the indigent poor, referred to in the statute as "sturdy beggars." The process of local taxation was to assess the cost to the locality and to spread it over property holders according to the values of their properties. For this purpose each particular piece of property had to be assessed and its yearly value worked out. A rate in the Pound was then levied on all property owners or occupiers. From that time there has grown up the system of making a valuation list of all properties in an area and this today is done by counties or corporations. The essential object of this valuation list is to assess the local rates. As, however, it is done by districts and is under local administration, it cannot be said that there is complete uniformity of practice between the various councils or boroughs so that in some areas you may have what are termed low rateable values, whereas in other areas you may have high rateable values. This is not necessarily important because the sum of money to be collected in the area is fixed by the needs of the district and if you have a high rateable value, a relatively low rate poundage will bring in the necessary money. In areas where low rateable values are the rule you will need a higher rate poundage to bring in the necessary funds. This is roughly the system of rating and valuation operative in England for local taxation and is today governed by the Rating and Valuation Act of 1925. Under that act a Central Valuation Committee was set up to make recommendations to secure as far as practicable that rating throughout the country was on a more uniform basis. These recommendations, however, had not the force of law and, as far as one can see, have not been effective in achieving the object intended.

When one deals with water rates, you will see that the new Water Act requires a rate to be made by the water undertakings. You will find this in Sec. 55 of the Third Schedule to the act.

The valuation list is the basis for charging the domestic water rate. The

total rateable values of the properties to be supplied are found first. Then, knowing the amount of money the water undertaking needs to cover its costs, a rate is fixed, which, when levied on the rateable value, will give the desired total income. This is, of course, a simple explanation. The problem is in practice more complex as account must be taken of water supplied by measure to industry, farms, restaurants, etc.

The valuation list for ordinary local rates is, however, used as a legal basis for working out water rates. Maximum rates and charges are fixed by Parliament (or under the new act, by the Minister of Health) for each undertaking. If the revenue does not reach the required sum, the deficit is charged to the local rate fund in the case of a municipal supply or, in the case of a company, is an ordinary trading loss.

A water rate is not a rate for the purpose of the Rating and Valuation Act of 1925, but is merely an easy method of assessing the charge on property supplied with water.

In England and Wales, water rates are not payable in general unless a supply of water is taken. In Scotland, water rates are payable on all hereditaments which are actually supplied or are within 200 yards of the supply of water.

The essential principle behind charging a water rate is to insure that the smallest properties shall have as much water as is necessary for domestic purposes, health, etc., and the metering system is avoided by this means and therefore there is no encouragement to the poor man to economize on his use of this essential service. It is also a rough and ready measure of actual use of water, but is not generally defended on those grounds, it being accepted that, in fact, the larger properties subsidize the smaller ones.

Subject to certain conditions being fulfilled, a householder is entitled, as of right, to demand a supply of water for domestic purposes upon payment or tender of the appropriate water charge. This does not preclude him seeking to obtain a supply of water by meter, but often a supply of water by measure is subject to a minimum charge equivalent to the sum which would be paid by way of domestic rate. For premises used partly for business, there is normally a provision in the statutes that such buildings may be supplied at the discretion of the water undertaking, by meter. Other schedules of charges are made and, depending upon the quantity of water likely to be used, are either a fixed annual or quarterly charge or by meter. The normal commercial supply of water is by meter.

Yours very sincerely,
(Signed) Leonard W. F. Millis
Secretary of the British Waterworks Association

29 August 1945

Summit, New Jersey—Survival and Retirement Experience With Water Works Facilities

As of December 31, 1940

THE Commonwealth Water Company is a privately-owned company serving a large metropolitan suburban area in Summit, Irvington and West Orange, and vicinities located in Essex, Union and Morris Counties, New Jersey.

Much of the territory served lies along the main line of the Delaware and Lackawanna Railroad extending westerly from Newark for a distance of about 20 mi. The elevation range is over 600 ft. The territory is ideally suited, and chiefly used, for residential purposes. It has had a healthy and steady increase in population over the last 30 years.

At Dec. 31, 1940, the company had 29,659 customers served wholly through meter measurement to an estimated population of 152,000. The system contained 433.5 mi. of main with 2,880 hydrants attached. The average daily pumpage was 10.4 mil.gal., equivalent to 68 gpd. per capita, of which approximately 81 per cent was accounted for by meter measurement. About 5 per cent of the water pumped was for industrial use.

Development of the Existing System

The original Commonwealth Water Company was incorporated May 15, 1889, and in June 1889 a contract was made between the company and the township of Summit (now the city of Summit) for the installation of a water works system. Construction was started and the property placed in operation in the early part of 1890. The original system consisted of wells and a pumping plant located in the Baltusrol Valley and some 5 mi. of distribution mains in Summit.

The company, as it exists today, is the result of the merger, purchase and consolidation of a considerable number of smaller companies. Until 1922 the development, ownership and management continued largely in the hands of the original Commonwealth Water Company. In that year, the American Water Works and Electric Company acquired the company through purchase and it has continued under its ownership and management until the present.

The territory now served includes the city of Summit, the townships of Millburn and Maplewood, the village of South Orange, the boro of New Providence, the townships of Springfield, Stirling, Millington and Meyersville in Passaic Township, the town of Irvington, and the townships of Hillside, Union, West Orange, Chatham, Livingston, Harding and New Providence.

The company has developed four sources of supply, namely: a surface supply at Canoe Brook and well supplies at Canoe Brook, Baltusrol and Short Hills. The largest of these supplies is the combined surface and well supply at Canoe Brook. This supply is located on the north side about mid-

TABLE 1

Summary of Mains

Summit, New Jersey

Size, in.	Kind	Total Feet	Identified Pipe: No. of Feet Installed	Percentage of Total	No. of Feet Retired	Percentage of Total	No. of Feet in Service	Percent age of Total	Year of First Installation	Average Age, yr.
2	Cast-iron unlined	1,524	0	0	0	0	0	0	—	—
3		11,024	0	0	0	0	0	0	—	—
4		211,327	161,831	9.2	5,501	12.2	156,330	9.1	1889	41.5
6		861,310	598,680	34.0	1,283	2.8	597,397	34.8	1889	26.8
8		136,018	87,640	5.0	382	0.8	87,258	5.1	1889	34.3
10		60,619	57,787	3.3	12	0.0	57,775	3.4	1889	44.1
12		42,387	33,430	1.9	0	0	33,430	1.9	1899	29.3
16		37,652	31,952	1.8	0	0	31,952	1.9	1899	22.0
18		2,233	2,233	0.1	0	0	2,233	0.1	1912	28.5
20		4,143	4,143	0.2	0	0	4,143	0.2	1912	28.4
24		14,186	14,186	0.8	0	0	14,186	0.8	1917	23.5
2	Cast-iron cement-lined	5,490	5,490	0.3	0	0	5,490	0.3	1934	2.8
4		803	803	0.1	0	0	803	0.1	1928	4.4
6		454,491	454,491	25.8	207	0.5	454,284	26.5	1927	8.8
8		78,520	78,520	4.5	412	0.9	78,108	4.5	1927	8.1
10		12	12	0.0	0	0	12	0.0	1930	10.5
12		58,508	58,508	3.3	0	0	58,508	3.4	1927	7.8
16		40,728	40,728	2.3	0	0	40,728	2.4	1927	8.0
24		6,297	6,297	0.4	0	0	6,297	0.4	1928	12.5
2	Cast-iron (Universal)	160	160	0.0	0	0	160	0.0	1927	13.5
3		5,920	2,362	0.1	0	0	2,362	0.1	1927	13.5
4		4,325	1,216	0.1	0	0	1,216	0.1	1915	22.3
6		39,521	36,228	2.1	0	0	36,228	2.1	1913	15.4
8		18,026	16,453	1.0	0	0	16,453	1.0	1921	14.1
¾	Galvanized steel	2,102	1,661	0.1	1,581	3.5	80	0.0	1903	15.5
1		7,525	760	0.0	177	0.4	583	0.0	1923	13.4
1¼		102	102	0.0	0	0	102	0.0	1923	17.5
1½		5,477	1,492	0.1	0	0	1,492	0.1	1924	10.8
2		19,337	5,964	0.3	188	0.4	5,776	0.3	1924	13.4
2½		1,140	190	0.0	190	0.4	0	0	1924	—
4		8,626	0	0	0	0	0	0	—	—
¾	Galvanized wrought-iron	7,697	2,533	0.1	1,568	3.7	875	0.1	1902	32.9
1		13,136	9,508	0.5	6,531	14.5	2,977	0.2	1891	35.7
1¼		773	0	0	0	0	0	0	—	—
1½		14,331	10,094	0.6	6,236	13.9	3,858	0.2	1896	35.1
2		44,939	36,038	2.0	20,337	45.2	15,701	0.9	1890	40.0
6	Wrought-iron	348	348	0.0	348	0.8	0	0	1889	—
1	Lead	93	62	0.0	0	0	62	0.0	1923	13.0
Total		2,220,850	1,761,902	100.0	45,043	100.0	1,716,859	100.0		21.9
Percentage of Total			100.00		2.56		97.44			
Average size, in.			6.95		2.21		7.08			

TABLE 1 (contd.)

Mortality Survival Ratios

Size, *in.*	Kind	No. of Feet	Period Covered, *yr.*	Percentage
4		161,831	51.5	96.566
6		598,680	51.5	99.592
8	Cast-iron unlined	87,640	51.5	99.515
10 and 12		91,217	51.5	99.987
Over 12		52,514	41.5	100.000
2–4		6,293	12.5	100.000
6	Cast-iron cement-lined	454,491	13.5	99.935
8		78,520	13.5	99.035
Over 8		105,545	13.5	100.000
2–8	Cast-iron (Universal)	56,419	27.5	100.000
¾–1½	Galvanized wrought-iron and steel, lead	26,212	48.5	29.485
2–2½	Galvanized wrought-iron and steel	42,192	49.5	38.553
6	Wrought-iron	348	15.5	0.000
Total		1,761,902		

TABLE 2

Summary of Valves

Summit, New Jersey

Size, *in.*	Number Installed	Number Identified	Number Retired	Number in Service	Year of First Installation	Average Age, *yr.*
4	1,463	1,042	65	977	1889	22.0
6	3,486	2,460	16	2,445	1889	10.7
8	193	132	2	130	1889	19.1
10	53	53	1	52	1889	23.2
12	44	28	0	28	1899	10.9
16	33	28	0	28	1912	8.9
18	2	2	0	2	1912	21.5
20	3	3	0	3	1912	10.8
24	7	7	0	7	1917	10.2
Total	5,284	3,756	84	3,672		14.2
Percentage of Total		100.00	2.24	97.76		

Mortality Survival Ratios

Size, *in.*	Number	Period Covered, *yr.*	Percentage
4	1,042	44.5	87.178
6	2,461	44.5	98.077
8	132	44.5	97.736
10 and 12	81	44.5	97.619
Over 12	40	21.5	100.000
Total	3,756		

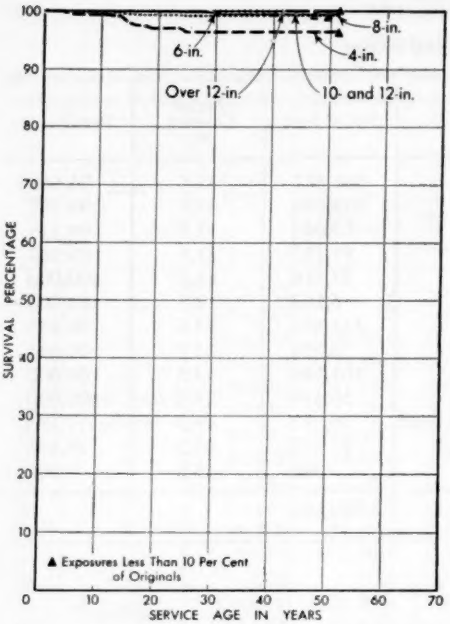

FIG. 1. Mortality Survival Curve—4–24-in. Cast-Iron Unlined Mains—Summit, New Jersey

BASE: Feet	SURVIVAL: 1889–1940	
SIZE	EXPOSURES	RETIREMENTS
in.	*ft.*	*ft.*
4	161,831	5,501
6	598,680	1,283
8	87,640	382
10 and 12	91,217	12
Over 12	52,514	0

way of the territory supplied. The company owns at this location about 650 acres of land. The water supply development consists of an underground supply developed by a series of air-lift and pumped wells and a surface supply formed by a storage reservoir of 730-mil.gal. capacity adjacent to Canoe Brook. Water from Canoe Brook, which is pumped into the storage reservoir, is treated and filtered before delivery into the distribution system.

Filters are the modern mechanical type, having a nominal capacity of 4

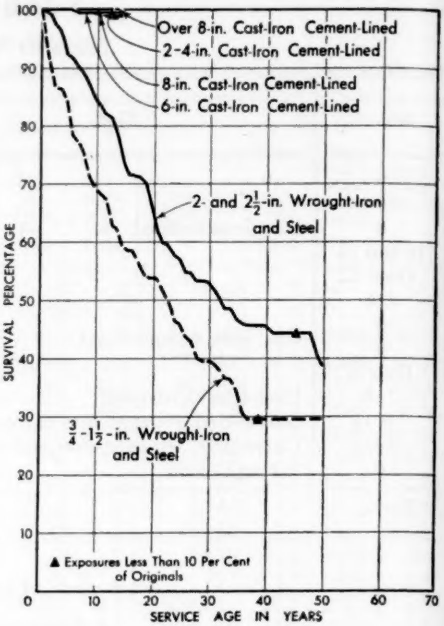

FIG. 2. Mortality Survival Curve—$\frac{3}{4}$–$2\frac{1}{2}$-in. Wrought-Iron and Steel and 2–24-in. Cast-Iron Cement-Lined Mains—Summit, New Jersey

BASE: Feet		SURVIVAL: 1890–1940	
SIZE	KIND	EXPOSURES	RETIREMENTS
in.		*ft.*	*ft.*
$\frac{3}{4}$–$1\frac{1}{2}$	Wrought-Iron and Steel	26,082	16,183
2 and $2\frac{1}{2}$	Wrought-Iron and Steel	42,192	20,715
2–4	Cast-Iron Cement-Lined	6,293	0
6	Cast-Iron Cement-Lined	454,491	207
8	Cast-Iron Cement-Lined	78,520	412
Over 8	Cast-Iron Cement-Lined	105,545	0

mgd. The capacity of the underground supply, as developed at Canoe Brook, is approximately 6 mgd. The pumping station at Canoe Brook, consisting of an engine, pump and boiler room, of fieldstone and masonry construction, houses the boilers, pumping and mechanical equipment. Surface and underground supplies, after delivery into a clear water basin, are pumped directly into the distribution system.

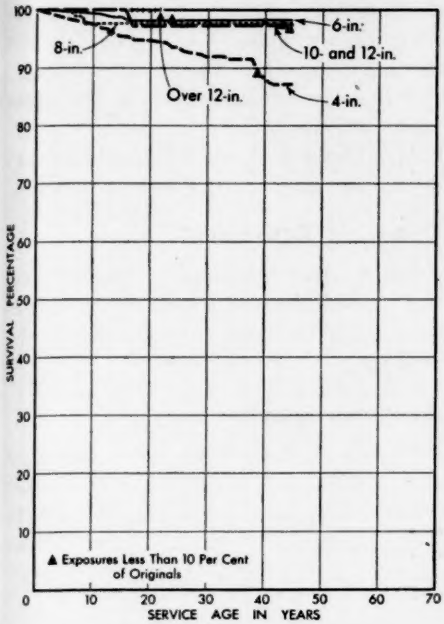

FIG. 3. Mortality Survival Curve—4–24-in. Valves—Summit, New Jersey

BASE: Unit SIZE	SURVIVAL: 1889–1933 EXPOSURES	RETIREMENTS
in.	*Units*	*Units*
4	1,042	65
6	2,461	16
8	132	2
10 and 12	81	1
Over 12	40	0

In the main part of the systems there are three storage reservoirs. Two, located in Maplewood, are known as Wyoming Reservoir No. 1 and No. 2, and have a capacity of 1 mil.gal. and 1.7 mil.gal., respectively. The other reservoir, known as West Orange Reservoir, is located in West Orange at the northeastern end of the system. This reservoir has a capacity of 1 mil-gal. All reservoirs are connected to the distribution system and act as equalizers. There are three small booster stations located in the distribution system served by the Canoe Brook Station.

In the same distribution system supplied from the Canoe Brook Station there is a second source of supply in the Short Hills area about 3 mi. to the southeast. The supply at this station is obtained from three pumped wells having an aggregate capacity of approximately 4.5 mgd. Water from the wells is delivered into a clear water basin from which the pumps take suction and deliver directly to the distribution system. This station is a substantial brick pump station housing two diesel-engine-driven centrifugal pumps with a gasoline-engine-driven standby unit. Located in the Short Hills Station are two motor-driven booster pumps which deliver water at higher pressure to a section of the Short Hills territory above the general supply level.

The Summit District territory is supplied from the Baltusrol Station. This system supplies, generally, the territory at the western end of the system. Water from this station is obtained from an underground source by means of infiltration galleries and wells. The water, after being delivered to receiving basins, is pumped into the Summit distribution system, which has an equalizing tank located at a high point. A substantial brick and masonry pump station at Baltusrol houses diesel-engine and steam-driven pumping equipment and boilers.

Basis of Study

The data on pipe and valves were compiled from a study made for the purpose of listing all pipe and valves that had been retired over the life of the property. The study was made coincidently with an inventory of existing mains. Company records pertaining to size, kind and date of installation were quite complete over the entire plant life except where systems

or parts of systems were purchased. Existing retirement records were checked and supplemented by a comparison of pipe and valves installed with the present existence in specific locations. The unknown pipe shown in the tabulations hereinafter consist of pipe purchased in the system prior to 1923.

The record on valves has not been carried forward beyond the date of the original study which was as of December 1933.

Mortality Survival Study

Mortality studies were made of mains and valves. Table 1 is a summary of the pipe installed, the amount retired and that still in service, as well as other pertinent data. Figures 1 and 2 show the mortality survival curves covering the amount and classification of pipe grouped as shown.

Table 2 and Fig. 3 show a similar study of valves.

A summary of the Class B facilities as of December 1933 is given below.

Causes of Retirement

There does not exist a complete record from which the causes of retirement of mains and valves could be determined.

Acknowledgment

The collection and compilation of data pertaining to the Commonwealth Water Company were carried out by the personnel of the American Water Works and Electric Company, Inc.

Summary of Class B Facilities

Summit, New Jersey

Impounding Reservoirs

Storage reservoir, capacity 735 mil.gal., formed by riprap covered earth embankment to which water is pumped from intake chamber formed by a concrete diverting dam across Canoe Brook which is 30 ft. long, maximum height of 6 ft. Constructed in 1929.

Wells

Kelly No. 1—Kelly type concrete cased well, 38-in. diameter, 135.5 ft. deep; cased for 59.5 ft., 75-ft. gravel encased screen; pumped by 24-in. motor-driven centrifugal deep well pump, 1,600-gpm. capacity. Installed in 1926.

Kelly No. 2—Same as No. 1 except pump is 1,050-gpm. capacity. Installed in 1927.

Kelly No. 3—Same as No. 1 except depth of 131 ft.; cased for 43 ft.; pump is 12 in., 1.5-mgd. capacity. Installed in 1932.

Kelly No. 4—Same as No. 1 except depth of 132 ft.; cased for 62 ft.; pump is 12 in., 900-gpm. capacity. Installed in 1933.

Layne A—Layne copperized steel cased well, 24-in. diameter, 121 ft. deep; cased for 85 ft.; pumped by a 15-in. motor-driven centrifugal deep well pump, 730-gpm. capacity. Installed in 1924.

Continental No. 1—Concrete cased well, 38-in. diameter, 105 ft. deep; cased for 55 ft., pumped by a 12-in. motor-driven centrifugal deep well pump, 450-gpm. capacity. Installed in 1929.

Well No. 26—Wrought-iron cased well, 10- and 8-in. diameter, 147 ft. deep, fully cased, slotted pipe strainer, pumped by air lift. Installed in 1910.

Well No. 31—Similar to No. 26, 8- and 6-in. diameter, 300 ft. deep; cased for 125 ft. Installed in 1916 and deepened in 1922.

Well No. 32—Similar to No. 26, 10- and 8-in. diameter, 196 ft. deep; cased for 136 ft. Installed in 1917 and deepened in 1922.

Well No. 33—Similar to No. 26, 10- and 8-in. diameter, 378 ft. deep; cased for 134 ft. Installed in 1917 and deepened in 1922.

Well No. 36—Similar to No. 26, 12-, 10- and 8-in. diameter, 303 ft. deep; cased for 128 ft. Installed in 1921.

Well No. 37—Similar to No. 26, 10- and 8-in. diameter, 304 ft. deep; cased for 101 ft. Installed in 1922.

Well No. 38—Similar to No. 26, 8-in. diameter, 300 ft. deep; cased for 136 ft. Installed in 1922.

Well No. 40—Similar to No. 26, 8-in. diameter, 300 ft. deep; cased for 139 ft. Installed in 1922.

Well No. 41—Similar to No. 26, 8-in. diameter, 303 ft. deep; cased for 142 ft. Installed in 1922.

Well No. 42—Similar to No. 26, 10- and 8-in. diameter, 306 ft. deep; cased for 142 ft. Installed in 1922.

Well No. 30—Gage well, wrought-iron cased well, 10- in. diameter, 137 ft. deep, fully cased. Installed in 1916.

Well No. 15—Wrought-iron cased well; 8-in. diameter, 300 ft. deep, cased for 60 ft.; pumped by motor-driven 8-in. centrifugal deep well pump. Installed in 1933.

Well No. 7—Wrought-iron cased well, 8-in. diameter, 200 ft. deep; cased for 46 ft.; pumped by air lift. Installed in 1910.

Well No. 8—Similar to No. 7 except 201 ft. deep; cased for 61 ft. Installed in 1911.

Well No. 12—Similar to No. 7 except 300 ft. deep; cased for 62 ft. Installed in 1913.

Well No. 14—Similar to No. 7 except 300 ft. deep; cased for 64 ft. Installed in 1913.

Well No. 16—Similar to No. 7 except 300 ft. deep; cased for 43 ft. Installed in 1925.

Well No. 39—Similar to No. 7 except 300 ft. deep; cased for 126 ft. Installed in 1922 and retired in 1930; reason unknown.

Kelly A—Concrete cased well, 38-in. diameter, 77 ft. deep; cased for 28 ft.; pumped by motor-driven 24-in. centrifugal deep well pump, capacity 1.5-mgd. Installed in 1930.

Kelly B—Same as A. Installed in 1931.

Infiltration Gallery

15- and 18-in. open-joint tile pipe laid in tunnels dug from shafts 22 ft. below surface; tunnel backfilled with screened gravel; 815 ft. long. Installed in 1889.

Pumping Equipment

Pump No. 2—Two 8-in. centrifugal pumps in series driven by 9-stage condensing steam turbine, 260 hp., capacity 3 mgd. at 288-ft. head. Installed in 1920.

Pump No. 3—Two 10-in. centrifugal pumps in series driven by 7-stage steam turbine, 300 hp., capacity 4 mgd. at 315-ft. head. Installed in 1922.

Snow Holly—Cross compound, condensing crank and flywheel steam pumping engine, rated 6-mgd. capacity at 325-ft. head. Installed in 1924.

DeLaval—Two-stage centrifugal pump driven by 11-stage steam turbine with attached 320-kw. generator, 970 hp., rated 6-mgd. capacity at 340-ft. head. Installed in 1927.

Baltusrol No. 1—Horizontal, compound, duplex, direct-acting condensing steam pumping engine, rated 1.5-mgd. capacity. Installed in 1910.

Baltusrol No. 2—Horizontal, triple-expansion condensing steam pumping engine, rated 3.0-mgd. capacity. Installed in 1907.

Low Service No. 1—Motor-driven centrifugal pumping unit, 40 hp., rated 8-mgd. capacity at 17-ft. head. Installed in 1929.

Low Service No. 2—Motor-driven centrifugal pumping unit, 20 hp., rated 7-mgd. capacity at 12-ft. head. Installed in 1929.

Low Service No. 3—Motor-driven centrifugal pumping unit, 20 hp., rated 5-mgd. capacity at 10-ft. head. Installed in 1929.

Kelly Well No. 1—Vertical, motor-driven deep well pump, 50 hp., rated 1,600-gpm. capacity at 90-ft. head. Installed in 1926.

Kelly Well No. 2—Vertical, motor-driven deep well pump, 150 hp., rated 1,050-gpm. capacity at 375-ft. head. Installed in 1927.

Kelly Well No. 3—Vertical, motor-driven deep well pump, 40 hp., rated 1.5-mgd. capacity at 90-ft. head. Installed in 1932.

Kelly Well No. 4—Vertical, motor-driven deep well pump, 40 hp., rated 900-gpm. capacity at 81-ft. head. Installed in 1929.

Layne Well A—Motor-driven deep well pump, 30 hp., rated 730-gpm. capacity at 96-ft. head. Installed in 1924.

Continental No. 1—Motor-driven deep well pump, 25 hp., rated 450-gpm. capacity at 105-ft. head. Installed in 1929.

Well No. 15—Motor-driven deep well pump, 15 hp., rated 440-gpm. capacity at 63-ft. head. Installed in 1933.

Kelly A—Motor-driven deep well pump, 25 hp., rated 1.5-mgd. capacity at 55-ft. head. Installed in 1930.

Kelly B—Same as Kelly A. Installed in 1931.

Booster No. 1—Motor-driven centrifugal pump, 20 hp., rated 350-gpm. capacity at 135-ft. head. Installed in 1931.

Booster No. 2—Two-stage motor-driven centrifugal pump, 30 hp., rated 290-gpm. capacity at 265-ft. head. Installed in 1931.

West Orange No. 1—Three-stage motor-driven centrifugal pump, 50 hp., rated 425-gpm. capacity at 296-ft. head. Installed in 1920.

West Orange No. 2—Same as West Orange No. 1.

Wyoming No. 1—Motor-driven centrifugal pump, 7.5 hp., rated 130-gpm. capacity at 130-ft. head. Installed in 1927.

Wyoming No. 2—Motor-driven centrifugal pump, 5 hp., rated 100 gpm. at 110-ft. head. Installed in 1927.

Wyoming No. 3—Motor-driven centrifugal pump, 15 hp., rated 325-gpm. capacity at 130-ft. head. Installed in 1932.

Luddington Road Booster—Motor-driven centrifugal pump, 20 hp., rated 2.25-mgd. capacity at 35-ft. head. Installed in 1929.

River Road Booster No. 1—Motor-driven centrifugal pump, 25 hp., rated 350-gpm. capacity at 190-ft. head. Installed in 1929.

River Road Booster No. 2—Motor-driven centrifugal pump, 25 hp., rated 400-gpm. capacity at 175-ft. head. Installed in 1931.

Compressor No. 3—1,500-cfm. steam-driven air compressor, 215 hp. Installed in 1922.

Compressor No. 4—1,574-cfm. motor-driven air compressor, 250 hp. Installed in 1929.

Compressor No. 1—652-cfm. steam-driven air compressor, 96 hp. Installed in 1914.

Snow Unit—Snow steam-engine-driven pump. Installed in 1895 and retired in 1931.

Compressor No. 2—821-cfm. steam-engine-driven air compressor, 113 hp. Installed in 1923.

Compressor No. 3—880-cfm. diesel-engine-driven air compressor, 144 hp. Installed in 1931.

Plant No. 4—Two-stage centrifugal pump, 1,575-gpm. capacity at 370-ft. head, driven by 216-hp. diesel engine with attached generating unit. Installed in 1931.

Plant No. 1—Three-stage centrifugal pump, 1.5-mgd. capacity at 385-ft. head, driven by 220-hp. gasoline engine with attached generating unit. Installed in 1931.

Plant No. 2—Two single-stage centrifugal pumps in series, 1.5-mgd. capacity at 375-ft. head, driven by 240-hp. diesel engine with attached generating unit. Installed in 1931.

Plant No. 3—Same as No. 2.

West Orange Booster No. 3—Two-stage centrifugal pump, rated 1-mgd. capacity at 300-ft. head, driven by 98-hp. gasoline engine. Installed in 1926.

Stirling—Horizontal duplex-belt-driven power pump, 0.1-mgd. capacity, driven by kerosene engine. Installed in 1924.

Low Pressure Steam Pump—Installed in 1894 and retired in 1917.

Manistee—Steam-turbine-driven pump. Installed in 1911 and retired in 1922.

Worthington—Compound steam pump. Installed in 1890 and retired in 1924.

Sweigard—Air compressor. Installed in 1911 and retired in 1922.

Ingersoll Rand—Air compressor. Installed in 1912 and retired in 1924.

Ingersoll Rand—Air compressor. Installed in 1908 and retired in 1924.

Motor-driven centrifugal pump. Installed in 1912 and retired in 1922.

Distribution Reservoirs

Wyoming—Concrete covered reservoir, 65.5 ft. wide by 108 ft. long, 23.3 ft. deep; capacity 1.25 mil.gal. Constructed in 1904.

West Orange—Concrete covered reservoir, 69 ft. wide by 102 ft. long, 22 ft. deep; capacity 1 mil.gal. Constructed in 1920.

Baltusrol—Concrete reservoir, wood roof, 24.83 ft. wide by 65.75 ft. long, 14.5 ft. deep; capacity 0.16 mil.gal. Constructed in 1896.

Stirling—Brick and concrete reservoir, wood roof, 33.67 ft. long by 33.42 ft. wide, 8.25 ft. deep; capacity 0.065 mil.gal. Constructed in 1927.

Standpipes

West Orange No. 1—Riveted steel standpipe, 35-ft. diameter, 35 ft. high; 250,000-gal. capacity. Erected in 1903.

West Orange No. 2—Riveted steel standpipe, 50-ft. diameter, 60 ft. high; 874,000-gal. capacity. Erected in 1928.

Short Hills—Riveted steel standpipe, 60 ft. diameter, 15 ft. high, 317,000-gal. capacity. Erected in 1907.

Druid Hill—Riveted steel standpipe, 40-ft. diameter, 65 ft. high; 600,000-gal. capacity. Erected in 1929.

Summary of Installations and Retirements
Summit, New Jersey

Mains

2-in. Cast-Iron Unlined Mains

Year Installed	*Feet Installed*	*Feet In Service*	*Feet Retired*
Unknown*	1,524	1,524	0
1940	0	0	0
Total	1,524	1,524	0

3-in. Cast-Iron Unlined Mains

Year Installed	*Feet Installed*	*Feet In Service*	*Feet Retired*
Unknown*	11,024	8,809	2,215
1940	0	0	0
Total	11,024	8,809	2,215

4-in. Cast-Iron Unlined Mains

Year Installed	*Feet Installed*	*Feet In Service*	*Feet Retired*
1889	9,631	9,330	301
1890	8,477	8,411	66
1891	8,562	8,562	0
1892	8,788	7,971	817
1893	13,440	12,655	785
1894	2,203	2,203	0
1895	6,048	5,823	225
1896	15,607	14,816	719
1897	7,725	7,725	0
1898	6,089	5,051	1,038
1899	8,427	7,844	583
1900	6,176	6,176	0
1901	7,555	7,096	459
1902	5,415	5,355	60
1903	6,554	6,554	0
1904	4,868	4,863	5
1905	1,909	1,909	0
1906	3,017	3,017	0
1907	3,447	3,447	0
1908	6,713	6,713	0
1909	7,163	6,948	215
1910	3,522	3,366	156
1911	2,460	2,460	0
1912	2,928	2,928	0
1913	1,895	1,895	0
1914	941	941	0
1915	1,372	1,372	0
1916	708	708	0
1917	37	37	0
1920	24	24	0
1922	6	6	0
1924	21	21	0
1925	23	23	0
1926	3	3	0
1927	27	27	0
1929	50	50	0
1940	0	0	0
Subtotal	161,831	156,330	5,501
Unknown*	49,496	49,496	0
Total	211,327	205,826	5,501

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*
1889	239	1905	62	1906
1890	66	1901		
1892	451	1905	366	1906
1893	785	1917		
1895	45	1917	180	1930
1896	203	1912	588	1914
1898	1,038	1912		
1899	583	1914		
1901	231	1912	228	1914
1902	60	1914		
1904	5	1914		
1909	215	1912		
1910	156	1914		

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

6-in. Cast-Iron Unlined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1889	4,812	4,756	56
1890	285	285	0
1891	2,175	2,175	0
1892	42,216	42,216	0
1893	5,175	5,175	0
1894	5,611	5,611	0
1895	2,417	2,121	296
1896	4,399	4,367	32
1897	10,413	10,413	0
1898	278	278	0
1899	2,644	2,644	0
1900	2,530	2,530	0
1901	10,671	10,463	208
1902	8,592	8,536	56
1903	4,502	4,502	0
1904	4,348	4,348	0
1905	10,810	10,810	0
1906	13,919	13,761	158
1907	10,708	10,708	0
1908	12,448	12,448	0
1909	24,282	24,282	0
1910	33,441	33,243	198
1911	22,699	22,699	0
1912	24,286	24,286	0
1913	21,808	21,808	0
1914	21,030	21,030	0
1915	18,319	18,319	0
1916	21,800	21,800	0
1917	5,095	5,095	0
1918	477	477	0
1919	3,475	3,475	0
1920	3,814	3,814	0
1921	11,666	11,666	0
1922	27,623	27,623	0
1923	33,056	33,056	0
1924	32,071	32,071	0
1925	48,890	48,890	0
1926	70,650	70,386	264
1927	15,218	15,218	0
1929	12	12	0
1930	15	0	15
1940	0	0	0
Subtotal	598,680	597,397	1,283
Unknown*	262,630	261,019	1,611
Total	861,310	858,416	2,894

Retirements by Years

Year Installed	Feet	Year
1889	56	1904
1895	296	1907
1896	32	1917
1901	208	1932
1903	56	1929
1906	158	1935
1910	198	1940
1926	264	1929
1930	15	1931

8-in. Cast-Iron Unlined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1889	5,262	5,151	111
1892	19,712	19,712	0
1896	434	434	0
1899	13,218	13,050	168
1904	1,423	1,423	0
1905	2,964	2,964	0
1906	2,746	2,746	0
1907	2,221	2,221	0
1908	192	192	0
1909	1,569	1,569	0
1910	2,532	2,532	0
1911	3,894	3,894	0
1912	4,815	4,815	0
1913	1,616	1,616	0
1914	2,344	2,344	0
1915	348	348	0
1916	1,541	1,438	103
1917	2,848	2,848	0
1919	1,234	1,234	0
1921	859	859	0
1922	1,315	1,315	0
1923	1,695	1,695	0
1924	3	3	0
1925	5,203	5,203	0
1926	3,633	3,633	0
1927	4,019	4,019	0

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

8-in. Cast-Iron Unlined Mains (contd.)

Year Installed	Feet Installed	Feet In Service	Feet Retired
1940	0	0	0
Subtotal	87,640	87,258	382
Unknown*	48,378	47,637	741
Total	136,018	134,895	1,123

Retirements by Years

Year Installed	Feet	Year
1889	111	1904
1899	168	1905
1916	103	1940

10-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1889	8,060	8,060	0
1890	33,226	33,226	0
1899	24	24	0
1904	12	0	12
1907	1,646	1,646	0
1909	5,327	5,327	0
1910	616	616	0
1911	2,903	2,903	0
1912	1,202	1,202	0
1917	1,172	1,172	0
1919	1,805	1,805	0
1920	14	14	0
1924	8	8	0
1926	1,420	1,420	0
1927	3	3	0
1928	349	349	0
1940	0	0	0
Subtotal	57,787	57,775	12
Unknown*	2,832	2,832	0
Total	60,619	60,607	12

Retirements by Years

Year Installed	Feet	Year
1904	12	1920

12-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1899	13,673	13,673	0
1911	3,915	3,915	0
1912	2,019	2,019	0
1917	896	896	0
1920	207	207	0
1923	5,149	5,149	0
1924	7,571	7,571	0
1940	0	0	0
Subtotal	33,430	33,430	0
Unknown*	8,957	8,957	0
Total	42,387	42,387	0

16-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1899	873	873	0
1904	758	758	0
1912	71	71	0
1915	722	722	0
1916	2,883	2,883	0
1919	1,292	1,292	0
1920	25,353	25,353	0
1940	0	0	0
Subtotal	31,952	31,952	0
Unknown*	5,700	5,700	0
Total	37,652	37,652	0

18-in. Cast-Iron Unlined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1912	2,233	2,233	0
1940	0	0	0
Total	2,233	2,233	0

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

20-in. Cast-Iron Unlined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1912	4,126	4,126	0
1928	17	17	0
1940	0	0	0
Total	4,143	4,143	0

24-in. Cast-Iron Unlined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1917	14,186	14,186	0
1940	0	0	0
Total	14,186	14,186	0

2-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1934	1,031	1,031	0
1935	408	408	0
1936	414	414	0
1937	53	53	0
1939	2,325	2,325	0
1940	1,259	1,259	0
Total	5,490	5,490	0

4-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1928	6	6	0
1929	38	38	0
1930	58	58	0
1931	2	2	0
1934	11	11	0
1935	138	138	0
1936	100	100	0
1937	186	186	0
1938	154	154	0
1939	61	61	0
1940	49	49	0
Total	803	803	0

6-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1927	53,935	53,935	0
1928	70,506	70,506	0
1929	83,276	83,276	0
1930	50,934	50,934	0
1931	36,578	36,371	207
1932	9,668	9,668	0
1933	503	503	0
1934	12,294	12,294	0
1935	12,133	12,133	0
1936	18,223	18,223	0
1937	47,996	47,996	0
1938	14,756	14,756	0
1939	11,739	11,739	0
1940	31,950	31,950	0
Total	454,491	454,284	207

Retirements by Years

Year *Installed*	*Feet*	*Year*
1931	207	1937

8-in. Cast-Iron Cement-Lined Mains

Year	Feet		
Installed	*Installed*	*In Service*	*Retired*
1927	3,030	3,030	0
1928	28,201	27,789	412
1929	7,112	7,112	0
1930	4,363	4,363	0
1931	3	3	0
1936	13,098	13,098	0
1937	9,798	9,798	0
1938	6,108	6,108	0
1939	4,268	4,268	0
1940	2,539	2,539	0
Total	78,520	78,108	412

Retirements by Years

Year *Installed*	*Feet*	*Year*
1928	412	1937

10-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1930	12	12	0
1940	0	0	0
Total	12	12	0

12-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	7,290	7,290	0
1928	11,106	11,106	0
1929	5,652	5,652	0
1930	12	12	0
1931	6,447	6,447	0
1934	4,912	4,912	0
1936	8,087	8,087	0
1939	14,995	14,995	0
1940	7	7	0
Total	58,508	58,508	0

16-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	12,620	12,620	0
1928	27	27	0
1929	3,279	3,279	0
1930	10,559	10,559	0
1940	14,243	14,243	0
Total	40,728	40,728	0

24-in. Cast-Iron Cement-Lined Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1928	6,297	6,297	0
1940	0	0	0
Total	6,297	6,297	0

2-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	160	160	0
1940	0	0	0
Total	160	160	0

3-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1927	2,362	2,362	0
1940	0	0	0
Subtotal	2,362	2,362	0
Unknown*	3,558	3,558	0
Total	5,920	5,920	0

4-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1915	440	440	0
1920	776	776	0
1940	0	0	0
Subtotal	1,216	1,216	0
Unknown*	3,109	3,109	0
Total	4,325	4,325	0

6-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1913	506	506	0
1920	1,200	1,200	0
1921	458	458	0
1922	3,324	3,324	0
1923	3,539	3,539	0
1924	1,347	1,347	0
1925	5,341	5,341	0
1926	6,979	6,979	0
1927	10,646	10,646	0
1928	2,626	2,626	0
1929	262	262	0
1940	0	0	0
Subtotal	36,228	36,228	0
Unknown*	3,293	3,293	0
Total	39,521	39,521	0

8-in. Cast-Iron Universal Mains

Year Installed	Feet Installed	Feet In Service	Feet Retired
1921	672	672	0
1923	1,281	1,281	0
1924	568	568	0

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

8-IN. CAST-IRON UNIVERSAL MAINS (contd.)

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1925	570	570	0
1926	2,267	2,267	0
1927	6,111	6,111	0
1928	4,984	4,984	0
1940	0	0	0
SUBTOTAL	16,453	16,453	0
Unknown*	1,573	1,573	0
TOTAL	18,026	18,026	0

¾-IN. GALVANIZED STEEL MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1903	589	0	589
1905	484	0	484
1906	119	0	119
1907	24	0	24
1911	212	0	212
1912	113	0	113
1922	40	0	40
1925	80	80	0
1940	0	0	0
SUBTOTAL	1,661	80	1,581
Unknown*	441	441	0
TOTAL	2,102	521	1,581

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*
1903	481	1926	108	1927
1905	434	1906	50	1927
1906	38	1927	81	1928
1907	24	1907		
1911	127	1913	85	1928
1912	113	1912		
1922	40	1932		

1-IN. GALVANIZED STEEL MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1923	269	92	177
1925	133	133	0
1929	358	358	0
1940	0	0	0
SUBTOTAL	760	583	177
Unknown*	6,765	3,923	2,842
TOTAL	7,525	4,506	3,019

1-IN. GALVANIZED STEEL MAINS (contd.)

Retirements by Years

Year Installed	*Feet*	*Year*
1923	177	1924

1¼-IN. GALVANIZED STEEL MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1923	102	102	0
1940	0	0	0
TOTAL	102	102	0

1½-IN. GALVANIZED STEEL MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1924	142	142	0
1926	390	390	0
1932	960	960	0
1940	0	0	0
SUBTOTAL	1,492	1,492	0
Unknown*	3,985	450	3,535
TOTAL	5,477	1,942	3,535

2-IN. GALVANIZED STEEL MAINS

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1924	816	816	0
1925	506	506	0
1926	32	0	32
1927	1,057	901	156
1928	3,255	3,255	0
1929	298	298	0
1940	0	0	0
SUBTOTAL	5,964	5,776	188
Unknown*	13,373	8,846	4,527
TOTAL	19,337	14,622	4,715

Retirements by Years

Year Installed	*Feet*	*Year*
1926	32	1929
1927	156	1928

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

2½-in. Galvanized Steel Mains

Year	Feet		
Installed	Installed	In Service	Retired
1924	190	0	190
1940	0	0	0
Subtotal	190	0	190
Unknown*	950	0	950
Total	1,140	0	1,140

Retirements by Years

Year Installed	Feet	Year
1924	190	1928

4-in. Galvanized Steel Mains

Year	Feet		
Installed	Installed	In Service	Retired
Unknown*	8,626	8,036	590
1940	0	0	0
Total	8,626	8,036	590

¾-in. Galvanized Wrought-Iron Mains

Year	Feet		
Installed	Installed	In Service	Retired
1902	132	132	0
1903	93	93	0
1904	76	0	76
1905	486	131	355
1906	150	150	0
1907	451	0	451
1908	98	40	58
1909	185	185	0
1910	52	52	0
1911	313	0	313
1912	156	0	156
1913	88	0	88
1920	161	0	161
1922	92	92	0
1940	0	0	0
Subtotal	2,533	875	1,658
Unknown*	5,164	906	4,258
Total	7,697	1,781	5,916

¾-in. Galvanized Wrought-Iron Mains (contd.)

Retirements by Years

Year Installed	Feet	Year
1904	76	1909
1905	355	1907
1907	451	1909
1908	58	1911
1911	313	1911
1912	156	1916
1913	88	1913
1920	161	1920

1-in. Galvanized Wrought-Iron Mains

Year	Feet		
Installed	Installed	In Service	Retired
1891	775	0	775
1892	316	194	122
1894	166	166	0
1896	337	337	0
1898	638	0	638
1900	309	0	309
1901	116	0	116
1902	411	411	0
1903	205	116	89
1904	946	0	946
1905	120	0	120
1906	468	181	287
1907	1,298	689	609
1908	272	0	272
1909	207	0	207
1910	1,053	399	654
1911	393	167	226
1912	1,085	0	1,085
1915	223	223	0
1920	170	94	76
1940	0	0	0
Subtotal	9,508	2,977	6,531
Unknown*	3,628	686	2,942
Total	13,136	3,663	9,473

Retirements by Years

Year Installed	Feet	Year	Feet	Year	Feet	Year
1891	294	1905	124	1910	210	1914
	147	1919				
1892	122	1904				
1898	410	1906	228	1912		

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

1-in. Galvanized Wrought-Iron Mains (contd.)

Retirements by Years (contd.)

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1900	44	1912	122	1915	143	1927
1901	116	1928				
1903	89	1928				
1904	673	1909	137	1912	136	1940
1905	120	1940				
1906	287	1912				
1907	396	1928	145	1929	68	1937
1908	55	1912	217	1916		
1909	207	1940				
1910	502	1910	95	1911	57	1925
1911	226	1912				
1912	246	1913	40	1917	235	1921
	564	1924				
1920	76	1927				

1¼-in. Galvanized Wrought-Iron Mains

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
Unknown*	773	753	20
1940	0	0	0
Total	773	753	20

1½-in. Galvanized Wrought-Iron Mains

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1896	506	0	506
1898	141	0	141
1899	694	694	0
1900	1,141	260	881
1901	1,189	74	1,115
1902	406	119	287
1903	849	517	332
1904	365	0	365
1905	680	0	680
1906	944	446	498
1907	910	573	337
1908	342	126	216
1909	50	0	50
1910	546	71	475
1911	441	441	0
1912	890	537	353
1940	0	0	0
Subtotal	10,094	3,858	6,236
Unknown*	4,237	598	3,639
Total	14,331	4,456	9,875

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1896	230	1906	276	1928		
1898	141	1911				
1900	42	1911	239	1912	238	1914
	362	1925				
1901	89	1903	64	1904	120	1905
	178	1912	16	1914	43	1927
	345	1928	260	1936		
1902	271	1911	16	1912		
1903	66	1911	266	1937		
1904	127	1909	158	1912	80	1916
1905	269	1912	411	1923		
1906	448	1911	50	1912		
1907	192	1912	145	1929		
1908	216	1915				
1909	50	1930				
1910	171	1914	304	1927		
1912	169	1929	184	1938		

2-in. Galvanized Wrought-Iron Mains

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1890	232	0	232
1891	4,932	1,340	3,592
1892	5,148	1,451	3,697
1893	2,302	96	2,206
1894	729	0	729
1895	2,280	120	2,160
1896	2,425	1,174	1,251
1897	1,822	1,143	679
1898	3,518	1,496	2,022
1899	3,823	3,570	253
1900	322	322	0
1901	354	0	354
1902	920	448	472
1903	292	40	252
1904	893	442	451
1905	1,270	169	1,101
1907	371	69	302
1909	411	411	0
1910	945	708	237
1911	867	867	0
1912	1,042	1,042	0
1913	572	508	64
1914	232	232	0
1919	53	53	0
1920	283	0	283
1940	0	0	0
Subtotal	36,038	15,701	20,337
Unknown*	8,951	1,497	7,454
Total	44,989	17,198	27,791

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

2-in. Galvanized Wrought-Iron Mains (contd.)

Retirements by Years

Year Installed	*Feet*	*Year*	*Feet*	*Year*	*Feet*	*Year*
1890	232	1901				
1891	625	1895	160	1897	733	1899
	623	1904	878	1905	320	1916
	88	1923	104	1927	61	1940
1892	81	1895	82	1896	757	1905
	348	1911	1,119	1912	588	1915
	14	1916	253	1917	182	1919
	273	1940				
1893	470	1895	74	1904	246	1905
	60	1906	225	1911	190	1912
	302	1914	299	1917	340	1927
1894	276	1903	327	1913	126	1919
1895	213	1898	322	1899	128	1907
	272	1909	151	1912	331	1914
	256	1915	265	1916	222	1930
1896	52	1904	495	1905	333	1915
	10	1927	361	1936		
1897	14	1904	206	1907	12	1914
	447	1927				
1898	13	1900	163	1901	320	1903
	52	1904	457	1905	171	1911
	566	1912	125	1916	155	1919
1899	210	1905	27	1928	16	1931
1901	52	1903	54	1904	206	1907
	42	1912				
1902	29	1904	28	1912	15	1914
	212	1915	188	1927		
1903	140	1912	112	1937		
1904	8	1909	80	1912	363	1936
1905	394	1915	277	1916	430	1936
1907	302	1911				
1910	111	1932	126	1937		
1913	64	1940				
1920	283	1922				

6-in. Wrought-Iron Mains

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1889	258	0	258
1894	90	0	90
1940	0	0	0
Total	348	0	348

Retirements by Years

Year Installed	*Feet*	*Year*
1889	258	1904
1894	90	1905

1-in. Lead Mains

Year	*Feet*		
Installed	*Installed*	*In Service*	*Retired*
1923	27	27	0
1931	35	35	0
1940	0	0	0
Subtotal	62	62	0
Unknown*	31	0	31
Total	93	62	31

* Unknown pipe listed consists of pipe purchased in system installed prior to 1923.

VALVES

4-in. Valves

Year	*Number*			*Year*	*Number*		
Installed	*Installed*	*In Service*	*Retired*	*Installed*	*Installed*	*In Service*	*Retired*
1889	21	18	3	1914	40	39	1
1890	41	38	3	1915	31	31	0
1891	16	14	2	1916	42	41	1
1892	17	14	3	1917	40	39	1
1893	13	10	3	1918	5	5	0
1894	4	4	0	1919	6	6	0
1895	13	11	2	1920	26	25	1
1896	19	18	1	1921	17	16	1
1897	13	13	0	1922	31	31	0
1898	16	13	3	1923	33	31	2
1899	33	28	5	1924	12	11	1
1900	12	9	3	1925	15	15	0
1901	26	23	3	1926	21	19	2
1902	22	20	2	1927	30	30	0
1903	14	13	1	1928	20	20	0
1904	16	16	0	1929	20	20	0
1905	53	48	5	1930	14	14	0
1906	36	34	2	1931	11	11	0
1907	17	15	2	1932	11	11	0
1908	22	20	2	1933	1	1	0
1909	36	31	5				
1910	27	25	2	Subtotal	1,042	977	65
1911	40	38	2	Unknown*	421	421	0
1912	67	66	1				
1913	22	22	0	Total	1,463	1,398	65

Retirement by Years

Year Installed	*Number*	*Year*	*Number*	*Year*	*Number*	*Year*	*Year Installed*	*Number*	*Year*	*Number*	*Year*	*Number*	*Year*
1889	1	1905	2	1906			1906	2	1931				
1890	1	1904	1	1928	1	1931	1907	1	1923	1	1929		
1891	1	1929	1	1930			1908	2	1931				
1892	1	1902	1	1905	1	1906	1909	3	1911	2	1912		
1893	1	1912	1	1926	1	1931	1910	1	1914	1	1924		
1895	1	1902	1	1905			1911	1	1912	1	1917		
1896	1	1912					1912	1	1912				
1898	1	1902	1	1912	1	1927	1914	1	1925				
1899	1	1907	2	1911	1	1912	1916	1	1927				
	1	1926					1917	1	1930				
1900	2	1905	1	1907			1920	1	1930				
1901	1	1912	1	1927			1921	1	1930				
1903	1	1914					1923	1	1925	1	1927		
1905	1	1912	1	1916	1	1926	1924	1	1929				
	1	1928	1	1931			1926	1	1927	1	1929		

* Unknown valves listed consist of valves purchased in system installed prior to 1923.

6-in. Valves

Year	Number			Year	Number		
Installed	Installed	In Service	Retired	Installed	Installed	In Service	Retired
1889	10	7	3	1915	36	36	0
1891	1	1	0	1916	48	48	0
1892	60	59	1	1917	13	13	0
1893	5	5	0	1918	1	1	0
1894	6	3	3	1919	6	6	0
1895	2	2	0	1920	13	13	0
1896	3	3	0	1921	23	21	2
1897	10	10	0	1922	45	45	0
1899	3	3	0	1923	66	66	0
1900	3	2	1	1924	93	92	1
1901	7	7	0	1925	164	164	0
1902	8	8	0	1926	258	258	0
1903	6	6	0	1927	288	288	0
1904	12	11	1	1928	329	329	0
1905	16	16	0	1929	303	303	0
1906	21	21	0	1930	149	148	1
1907	18	18	0	1931	142	142	0
1908	12	12	0	1932	38	38	0
1909	27	27	0	1933	3	3	0
1910	48	48	0				
1911	42	40	2	SUBTOTAL	2,461	2,445	16
1912	45	45	0	Unknown*	1,025	1,006	19
1913	45	44	1				
1914	33	33	0	TOTAL	3,486	3,451	35

Retirements by Years

Year Installed	Number	Year	Number	Year	Number	Year	Year Installed	Number	Year	Number	Year	Number	Year
1889	3	1904					1911	1	1919	1	1924		
1892	1	1902					1913	1	1920				
1894	1	1902	1	1905	1	1910	1921	2	1923				
1900	1	1912					1924	1	1924				
1904	1	1910					1930	1	1931				

8-in. Valves

Year	Number			Year	Number		
Installed	Installed	In Service	Retired	Installed	Installed	In Service	Retired
1889	6	6	0	1914	3	3	0
1892	21	21	0	1915	1	1	0
1896	1	1	0	1916	2	2	0
1899	4	3	1	1917	5	5	0
1903	1	1	0	1919	2	1	1
1904	1	1	0	1921	1	1	0
1905	4	4	0	1923	3	3	0
1906	4	4	0	1924	1	1	0
1907	2	2	0	1925	7	7	0
1908	1	1	0	1926	1	1	0
1909	1	1	0	1927	13	13	0
1911	3	3	0	1928	22	22	0
1912	7	7	0	1929	10	10	0
1913	1	1	0				

* Unknown valves listed consist of valves purchased in system installed prior to 1923.

8-in. Valves (contd.)

Year Installed	*Number Installed*	*In Service*	*Retired*
1930	3	3	0
1931	1	1	0
1933	0	0	0
Subtotal	132	130	2
Unknown*	61	58	3
Total	193	188	5

Retirements by Years

Year Installed	*Number*	*Year*
1899	1	1905
1919	1	1927

10-in. Valves

Year Installed	*Number Installed*	*In Service*	*Retired*
1889	5	5	0
1890	9	9	0
1896	1	1	0
1899	1	1	0
1904	1	0	1
1907	1	1	0
1908	1	1	0
1909	3	3	0
1910	1	1	0
1911	3	3	0
1912	4	4	0
1916	1	1	0
1917	4	4	0
1919	1	1	0
1923	3	3	0
1924	3	3	0
1926	3	3	0
1927	2	2	0
1928	3	3	0
1930	2	2	0
1931	1	1	0
1933	0	0	0
Total	53	52	1

Retirements by Years

Year Installed	*Number*	*Year*
1904	1	1920

12-in. Valves

Year Installed	*Number Installed*	*In Service*	*Retired*
1899	3	3	0
1911	2	2	0
1912	1	1	0
1917	1	1	0
1923	1	1	0
1924	2	2	0
1927	2	2	0
1928	7	7	0
1929	6	6	0
1930	2	2	0
1931	1	1	0
1933	0	0	0
Subtotal	28	28	0
Unknown*	16	16	0
Total	44	44	0

* Unknown valves listed consist of valves purchased in system installed prior to 1923.

16-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1912	1	1	0
1915	2	2	0
1919	1	1	0
1920	8	8	0
1927	4	4	0
1928	2	2	0
1929	1	1	0
1930	4	4	0
1931	5	5	0
1933	0	0	0
	—	—	—
SUBTOTAL	28	28	0
Unknown*	5	5	0
	—	—	—
TOTAL	33	33	0

18-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1912	2	2	0
1933	0	0	0
	—	—	—
TOTAL	2	2	0

20-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1912	1	1	0
1928	2	2	0
1933	0	0	0
	—	—	—
TOTAL	3	3	0

24-IN. VALVES

Year	Number		
Installed	Installed	In Service	Retired
1917	3	3	0
1928	4	4	0
1933	0	0	0
	—	—	—
TOTAL	7	7	0

* Unknown valves listed consist of valves purchased in system installed prior to 1923.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **34:** 412 (Mar. '42) indicates volume 34, page 412, issue dated March 1942. If the publication is paged by the issue, **34:** 3: 56 (Mar. '42) indicates volume 34, number 3, page 56, issue dated March 1942. Initials following an abstract indicate reproduction, by permission, from periodicals, as follows: *B.H.—Bulletin of Hygiene (British); C.A.—Chemical Abstracts; P.H.E.A.—Public Health Engineering Abstracts; W.P.R.—Water Pollution Research (British); I.M.—Institute of Metals (British).*

CORROSION AND CORROSION CONTROL

Corrosion of Yellow Brass Pipes in Domestic Hot Water Systems—A Metallographic Study. E. P. Polushkin & Henry L. Shuldener. Metals Technology (Oct. '44). Microstructural observations on 400 brass pipe specimens, collected during 5 yr., after exposure to soft waters of low pH, low alky. and silica at New York City, Jamaica, L.I., Rockaway, N.Y., and Philadelphia. Oxygen satn. before heating avgd. 80%. Pipes classified into 2 groups: (1) copper content 60–62% (Muntz metal), and (2) copper content 65–68% (high brass). Muntz metal contains 2 solid solns.: alpha and beta, whose proportion varies according to zinc content and rate of cooling; high brass contains only alpha. Actual service life detd. by local corrosion (plug type) rather than by slower general corrosion. Frequently badly dezincified specimens located close to sound sections. Below mineral deposit, layer of cuprous oxide bound directly to pitted underlying metal. Microstructure detd. by etching with (1) ammonium hydroxide contg. few drops of hydrogen peroxide and (2) ammonium persulfate soln. All specimens showed general corrosion, differences being only in depth of penetration. Measured rates of penetration generally less than $\frac{1}{40}$ mm. per yr., but in one pipe exceeded $\frac{1}{2}$ mm. per yr. No relation indicated between grain size and depth of corrosion. Alpha brass corroded in 2 steps: first, alpha destroyed and replaced by metallic copper; second, copper oxidized, amt. of oxide increasing in proximity to pipe. General corrosion of alpha-beta brass occurs stepwise as above, but is distinguished by preferential attack on beta. In local corrosion, very common in both alpha and alpha-beta brass, zinc is removed, copper deposited and partially oxidized. Large local accumulation of copper, commonly termed "plug," may extend through full thickness of pipe wall. Plugs mounded over by white or yellowish tubercule; hypothetical compn., calcd. for one anal., showed zinc hydroxide 61%, zinc carbonate 22% and cuprous oxide 2%, balance being small amts. of iron hydroxide, silica and combined water. Three types of plugs found: (1) all original metal dezincified; (2) only beta dezincified and alpha intact; and (3) plugs similar to first type but developing from layer of corrosion products. In some cases local corrosion initiated in areas bearing residual stresses, as caused by cold-drawing or surface defects. Residual origin of copper derived by dezincification of alpha established by successful search for twinned alpha grains; in beta, no criterion possible between residual or redeposition concepts, since beta does not twin. Attack on beta always precedes that of alpha; dezincification of beta often gradual, but that of alpha always abrupt. Alternating zones in plugs and zonal structure of tubercules indicate periodicity of corrosion.—*A. A. Hirsch.*

Investigation of External Corrosion of Mains of a Centralized Water Supply System. O. Hannemann. Gas-u. Wasser. (Ger.) **83:** 229 ('40). Water mains laid in clay showed large number of perforations and considerable graphitization after they had been in use for 20 yr. Deposits of iron sulfide found on outer surfaces of mains. Anals. of soil and ground water in neighborhood of mains showed that soil contained only small amts. of sulfate and sulfide, but many samples con-

tained large amts. of sulfate. No hydrogen sulfide found in either soil or ground water. Thought that clay originally contained much iron pyrites which under influence of oxygen in soil or of water contg. oxygen became oxidized to ferrous sulfate, with formation of sulfuric acid. Part of ferrous sulfate reacted with calcium carbonate to form calcium sulfate and ferrous carbonate, which later was converted to ferrous hydroxide. Sulfuric acid reacted with sulfide, liberating hydrogen sulfide, and with calcium carbonate to form calcium sulfate. Amt. of sulfuric acid formed, although small, sufficient to have appreciable effect on iron pipes in course of 20 yr. Acid dissolves iron, particularly from upper half of pipe; hydrogen sulfide, on other hand, in very dil. soln. acts mainly on under side of pipe. Possible that galvanic corrosion also occurs, graphite forming one electrode and iron other electrode, in very dil. acid soln. contg. sulfate. Pipes in such soils can be protected by coating with tar products or by packing small pieces of limestone around pipe to neutralize sulfuric acid; aggressive water should be drained away from pipe as rapidly as possible.—*W.P.R.*

The Corrosion of Mains in Clay Soils. H. J. Bunker. Surveyor (Br.) **102**: 443, 459 (Oct. 29, Nov. 5, '43) (*Abstracted*, Jour. A. W. W. A. **36:** 597 ('43)). *Discussion.* J. Inst. San. Engrs. (Br.) **5**: 211 ('44). R. Lessing: Describes case in which corrosion occurred at certain points close together in elec. cable sheathed in lead, wrapped in Hessian coated with bitumen and wound with steel tape. Bacteria decomposed cellulose of Hessian; carbon dioxide liberated attacked lead. C. Pain: Coating with bitumen increased cost of water main by 20%. G. Miles: Water drawn from ends of extensive water supply systems sometimes contained much hydrogen sulfide and much iron in soln., when content of sulfate in water was little above normal. Aeration of water caused these substances to disappear. G. Smethurst: Lead service pipes did not corrode in Gault clay but did sometimes corrode in Lias and Oxford clays. Wrought-iron pipes gave satisfactory service in clay soils but pipes of mild steel corroded very quickly. A. V. Hussey: Suggests that Hessian dipped in cement slurry would prevent corrosion of pipes in clay soils. *Author's reply:* Sulfate-reducing bacteria widespread and iron appeared to stimulate their development. Bacteria could utilize hydrogen produced in process of corrosion. Such bacteria found in soil to depth of at least 100′ and in oil wells at depth of 3000′. Absence of org. matter at great depths in soil limited development of bacteria. Bacteria could develop in stagnant region in close proximity to aerated liquid, as for example under thick deposit of rust inside water main. Iron bacteria, such as *Crenothrix polyspora*, do not normally occur together with sulfate-reducing bacteria as aerobic iron bacteria. Surrounding pipes with sand or gravel appeared to be satisfactory method of preventing corrosion even though surrounding clay impervious to water. Putting clay over top of pipes bedded in sand or gravel would tend to create anaerobic conditions around pipe. Corrosion of asbestos-cement pipes in soil appeared to be mainly chem. Aeration would control sulfate-reducing bacteria but it might increase chem. corrosion. No convincing evidence that sulfate-reducing bacteria could utilize bitumen as source of org. matter but suspected that they could use cellulose. *Discussion. Op. cit.* Surveyor (Br.) **104**: 387 (July 3, '45). F. Merrill: Crewe adopted spun-iron pipes about '27–'28. In '38 two bursts occurred. Anals. of soil and of pipe have been made without light being shed on cause of trouble. Majority of bursts occur with vertically-cast pipe. Pipe appears sound from outside but if metal is broken graphitization has taken place, in some cases right through metal. Corrosion may be due to electrolysis, or where sulfates present in subsoil. Disadvantages of coatings formed by dipping in patent soln. include: (1) thickness, (2) pinholes, (3) damage in transportation and laying and (4) lack of continuous coating over joints. Hessian wrapping of little value. Only satisfactory way to overcome trouble is to sheath pipes in bitumen and carry this sheathing over joints in manner similar to that adopted for steel mains. J. Birtwistle: Troubles with pipe corrosion at Northwich over 34 yr. include: (1) Traces of peat or vegetable matter appear in subsoil. Peaty acidity may be cause. (2) Corrosion had perforated pipe with holes from ½″ to 1½″×8″. Metal in defective sections could be easily picked and cut by penknife, revealing something like pure graphite. (3) Interior surfaces of pipes generally good. Trouble localized within lengths of 3 to 60 yd. Graphitization has been found in spun-iron pipes in one

instance only. Coating applied to pipes not adequately controlled. Second dipping might have good effect. Spun-iron pipes resist normal corrosion due to compactness of molecules. P. HEATON: In '29 it was necessary to renew many lengths of c-i. pipe in use from 30 to 60 yr. Fractures occurred when temp. fell. Sections taken out were lighter than cast iron. When wet they could be cut with knife; when dry they were hard and brittle. Mfrs. reported cause was "soil corrosion," and termed action "auto-electrolysis." Clinkers next to pipes have been found to protect them from soil corrosion. Spun pipe by no means answer to corrosion. In '37 serious corrosion found in spun pipes. Examn. of such corroded pipe showed: (1) Iron and metalloids oxidized and graphitized in situ. (2) Ferrous sulfide present. (3) Corrosion due to interaction of salts in soln. from clay, reacting with carbon in iron forming galvanic cell, iron going into soln. and being oxidized to ferric oxide. Reaction takes place under anaerobic conditions and is confirmed by presence of iron sulfide. (4) There were small amts. of coke, coal and ashes, tar macadam and org. matter in clay. (5) Water content of clay was 18%. (6) pH of clay was 5.5. Intention, henceforth, to surround pipes with sand, since no case of corrosion of pipe has been found in sand.—*H. E. Babbitt.*

Some Cases of Corrosion in Engineering Practice. G. H. STANLEY. J. S. African Inst. Engrs. **42**: 135 ('42). Causes of corrosion discussed and cases of corrosion observed by author described. Cases of corrosion of ferrous metals include 3 cases of localized corrosion and perforation of water mains; in 2 cases mains were of steel and in 1 case of wrought iron. In all 3 cases coating or lining on pipe had failed. In one case river water passing through main had previously been treated with gypsum and aluminum sulfate, but before corrosion was observed use of lime, aluminum sulfate and chlorine substituted for the previous treatment. In this connection the author made some expts. in which loss in weight observed of iron wire in contact with raw river water and treated water. In 3 wk. wire in contact with water treated with aluminum sulfate and gypsum lost 27% of its weight and wire in contact with water treated with aluminum sulfate and lime lost 23%. Removal of air prevented corrosion almost entirely. If metal of pipe of heterogeneous structure, pitting and irregular corrosion facilitated, but corrosion cannot occur unless water has access to pipe. Case in which irregularity of structure chief cause of corrosion observed in casing of condenser where, after years of service, some heads of steel rivets had corroded away completely, whereas condenser itself did not show abnormal corrosion. Meteorite showed localized corrosion where it contained inclusions of sulfide and chloride. In another series of expts. shown that de-aeration of water considerably reduced amt. of corrosion of iron wire immersed in water which had been treated with lime. In another expt. strip of steel bent at right angle placed in container with vertical leg of steel inside glass tube; enough water added to container to immerse whole strip. Horizontal leg had been heated to redness before immersion in water and was therefore covered with scale. After immersion for several weeks horizontal leg corroded little. Glass tube choked with rust and rust also deposited on bottom of container. Bubbles of gas slowly given off from tube. Among cases of corrosion of non-ferrous metals observed was corrosion of bronze pump impeller operating in sea water. Bronze contained 3.5% lead which occurred as inclusions. In another case condenser tubes of brass pitted and perforated; one tube, similar in structure and compn. to corroded tubes, unaffected. Thought that some foreign material or product of corrosion had lodged in tubes and initiated local attack. Some condenser tubes of alpha brass contg. tin corroded evenly and showed little dezincification, whereas other tubes of alpha brass contg. no tin under same conditions showed severe dezincification and were perforated. Water had pH value between 5 and 6 and was scale-forming. Superiority of brass contg. tin does not appear to be due to formation of protective coating of oxidized tin. Same kinds of tubes used in constr. of oil coolers; after several years those contg. tin not corroded, whereas those contg. no tin showed severe localized dezincification and were perforated in some places. At power station, 2 types of cooler with copper tubes used for cooling turbine and transformer oil. In turbine oil cooler tubes vertical and in transformer oil cooler horizontal. Water used same in both types of cooler; has pH value of 8.7 and has not caused much corrosion of other metal parts. Perforations occurred first in tubes of turbine oil cooler after they had been in use

for about a year. Pits started from inside, i.e., water side of tubes. Almost all perforated tubes examd. showed extensive black scale of copper oxide, whereas uncorroded tubes had smooth olive-green patina. As result of observations and expts. concluded that corrosion occurred where tubes had surface defects, such as small pores, included foreign material or broken mill scale. In case of tubes in transformer oil cooler their horizontal position appeared not to affect type of corrosion. Tubes tinned on outside and some had some tin on inner surfaces which had originated from solder used for soldering tubes into brass tube plates. Tinning, either by solder itself or by accompanying flux, appeared to be prime cause of corrosion; presence of copper oxide scale appeared to be important secondary factor. Scale of copper oxide itself resistant to corrosion but brittle; where it had cracked, electrolytic action occurred. Expts. made to det. effect of various factors on corrosion of copper described. Difficulty experienced in producing corrosion in water used in oil coolers, even when pieces of tubes used which had failed in service. Concluded from results of expts. that this water is not corrosive to clean copper but that layer of copper oxide scale can initiate pitting. Absence of attack on partially tinned copper appears to indicate that it was flux rather than solder itself which was responsible for failure of partially tinned copper tubes. Coating of soft mud does not increase corrosion. Case of corrosion of lead occurred on joints where connection made between lead storage batteries and busbars. Material used for burning joints old lead cable sheathing which had different compn. and different microstructure from those of lugs. Corrosion of lead sheaths of cables generally due to ineffective wrapping; where Hessian wrapping, impregnated with bitumen, has too open a weave, corrosion occurs except where the Hessian overlaps and forms a double layer. Serious corrosion and fractures occurred in cable formed of stranded aluminum wires surrounding galvanized steel wire. Loose white product, which contd. zinc as well as aluminum, formed. Corrosion product from steel contd. chloride. Thought that spots of flux contg. deliquescent chloride not removed from wire before cable made. Strand of aluminum wire slightly moistened with soln. of zinc chloride and kept in loosely stoppered glass tube continued to corrode for more than 2 yr. R. H. HARRISS: Described effects of vibration and grain of metal on corrosion. J. P. LESLIE: Described corrosion of suction impellers of multi-stage pumps; by imposing small pos. head on suction side of pumps corrosion elimd. Corp. of Cape Town constructing plant designed to remove color from water supply and to increase pH value from about 5.1 to 9.1; treated water should cause no corrosion of distr. system, plumbosolvency should be reduced and it should be possible to use copper pipes. Bitumen linings for water pipes should be $\frac{3}{16}$ to $\frac{1}{4}$ in. thick; thicker linings do not adhere as well to steel pipes.—*W.P.R.*

The Action of Water on Lead. E. A. G. LIDDIARD & P. E. BANKES. Wtr. & Wtr. Eng. (Br.) **48**: 127 (Mar. '45). Extracts from J. Soc. Chem. Ind. **43**: 39 (Feb. '43). Action of water on lead studied by measuring rate of attack by distd. water in equil. with air contg. known quants. of carbon dioxide. Separate and combined effects of added sodium and calcium bicarbonate, sodium chloride, calcium sulfate and chlorination detd. Main conclusions drawn are: (1) Oxygen plays essential part in dissoln. of lead by water. Oxygen content of all natural waters sufficient to assure that first stage in action of water on lead is completed. (2) In distd. or very soft water, contg. only traces of CO_2, first effect on lead is comparatively heavy attack with formation of white ppt. of basic lead carbonate. In time reaction tends to be stifled owing to formation of insol. film of basic lead carbonate on surface of lead. Amt. of lead going into soln. increases with increase of CO_2. (3) Presence of sodium or calcium bicarbonate in soln. favors formation on lead surface of film which is completely protective even in presence of CO_2. 40 ppm. calcium bicarbonate sufficient to inhibit attack by distd. water contg. substantial quants. of CO_2. (4) Attack on lead by distd. water contg. free CO_2, and by bicarbonate solns. contg. free CO_2, increased by addn. of chloride as sodium chloride. Attack increases with increase in chloride concn. Addns. up to approx. 60 ppm. of NaCl have most marked effect. Addn. of calcium bicarbonate to distd. water contg. NaCl decreases rate of attack. Chloride interferes with formation of protective film. (5) Addn. of $CaSO_4$ to either distd. water or solns. of bicarbonate and distd. water has no effect on its plumbosolvency. (6) Chlorination of distd. water or of a public water supply to give free chlorine content up to 0.2 ppm. had

no marked effect of water on lead. (7) Initial action of distd. water or soft water contg. only traces of CO_2 can be suppressed by pre-exposure of lead to solns. of calcium and sodium bicarbonate. Such films have no permanent protective action on waters contg. appreciable quants. of CO_2. Protection against initial attack in these waters also obtained by pretreatment of lead with sodium silicate or sodium sulfide. Treatment with solns. of phosphates, sulfates, and sulfites gives no initial protection. Pretreatment of lead pipes not permanently effective in reducing amt. of lead taken up by water forming no protective scale. Soft water comparatively low in free CO_2 can safely be handled in lead, provided initial attack is suppressed either by pretreatment of lead pipes or by allowing water to circulate in pipes sufficiently long to form protective film. When free CO_2 content rises, however, lead dissolved increases unless there is sufficient sodium or calcium bicarbonate in soln. Permanent hardness of water offers no protection. Waters high in chlorides liable to take up lead, particularly if they also contain excess of CO_2. Treatment of water with lime will prevent attack on lead. Sodium silicate reduces action of water on lead. Softening by base-exchange process unlikely to cause increased action on lead.—*H. E. Babbitt.*

The Influence of Biological Processes on Corrosion of Structural Materials. L. W. Haase. Korrosion u. Metallschutz. (Ger.) **16**: 155 ('40); Gas-u. Wasser. (Ger.) **83**: 555 ('40). Presence of some bacteria, algae or fungi on structural materials can cause corrosion or accelerate existing corrosion. In one instance, species of *Fusarium* caused extensive corrosion of turbine blades. Decompn. of organisms caused liberation of sulfur which combined with iron on surface of blades to form iron sulfide. In another case corrosion of oil-cooling pipes and of blades of c-i. turbines caused by heavy growths of *Sphaerotilus natans*. Covering of fungus on metal prevented access of oxygen and promoted production of hydrogen sulfide and soln. of metal. External corrosion of open cooling plant caused by algae on metal surfaces. Algal layer in contact with metal killed by heat and decomposed. Slime produced contained when dry more than 50% combustible matter, in addn. to divalent and trivalent iron, iron sulfide and some lime. Also contained large amts. of silica, which did not, however, arise from algae. Methods of preventing growth of algae include treatment with chlorine and copper compds., production of protective layers with org. chromium compds., and deacidification and filtration of circulating water. In water works corrosion largely due to iron bacteria, mainly species of *Gallionella*, which can be controlled by increasing oxygen content, and to *Zoogloea*, which can be removed by treatment with chloramine.—*W.P.R.*

Experiences With the Permutit-Elektroschutz Method. G. Seelmeyer. Heizg u. Luftg (Ger.) **16**: 7: 79 ('42); Gesundh-Ing. (Ger.) **66**: 129 ('43). Various elec. methods described for prevention of corrosion of constr. materials, for prevention of formation of scale and for removal of scale. In Permutit-Elektroschutz method (Permutit E-S method) one or more Al anodes placed in water of hot-water tank so that they are surrounded by hottest water. Direct current of 0.6 to 5.0 amp. passed through wall of tank. After treatment for 15 min. hot water loses its corrosive properties. Method has advantages that no chems. required and no complicated mechanism, but elec. app. needs careful supervision. Of 61 plants using this method 34 no longer experience corrosion; *in the remainder little or no improvement has occurred.* In most cases adherent scale not produced but sludge formed which had to be removed continuously. Character of water has effect on results obtained by this method but content of dissolved O in water has little effect. Temps. of more than 70° and high pressures deleterious. Current strength required in theory is 2 amp./cu.m. of tank capac.; with deviations of more than 50% from this value corrosion occurs again immediately.—*C.A.*

The Spraying of Metals by the Gas Method. S. Brennert. Teknisk Tidskrift (Swedish) **73**: B61 ('43); Iron Steel Inst., Bul. *No.* 95: 23A. Author describes metal-spraying pistols and prepn. of surface to be sprayed and discusses properties of coatings of different metals. Curves presented showing how porosity of coatings of zinc, iron, lead, Monel metal and copper decreases with increasing thickness. With zinc and aluminum coatings on iron and steel, base metal protected by a galvanic effect, and not essential for coating to be completely impervious to moisture. Thicknesses of about 0.15 mm. for zinc and

0.20 mm. for aluminum sufficient. With noble metals, however, coating must be impervious to moisture, for here iron goes into soln. and atomic hydrogen forms on sprayed metal. Thickness of coating must therefore be greater.—*I.M.*

Corrosion in Electrical Machinery. W. Subak. Elec. Review **129**: 192 ('41); Elec. Eng. Abs. **44**: 238 ('41). When atm. action cause of corrosion, effect may be reduced by providing adequate ventilation, enclosing machine, providing drainage to remove condensed water, and installing permanent heaters in machine, which are used to keep machine warm when idle. Electrolytic corrosion may be due to elec. current in bearings, electrodes being shaft end and brasses, and oil acting as electrolyte. Circuit may be interrupted by insulating one of bearings from pedestal. Alternating fluxes having similar effects may be elimd. by special designs. Parts subjected to corrosion fatigue may be protected by cadmium plating. Synthetic resin varnishes have great value for protection of parts of mchy.—*I.M.*

Behavior of Two Cast Zinc Alloys in Tap Water Under Operating Conditions. Friedrich Bischof. Maschinenbau (Ger.) **21**: 297 ('42); Chem. Zentr. (Ger.) **114**: 1613 ('43). Alloy contg. 87.98% zinc, 9.97% aluminum, 0.97% lead, 0.96% copper, 0.04% manganese, and 0.08% silicon used for cast coatings on hot and cold water pipes. After 1–1½ years' service, presence of cracks made them no longer usable. This extensive destruction due to high lead content. In this case alloy used unsuitable for purpose because of its tendency to intercrystalline corrosion. Series of these nipples peeled after about 18 months' use. Cause of this cracking or peeling found to be pitting of surface and in interior of metal.—*I.M.*

On the Question of the Intercrystalline Corrosion of Zinc Alloys. Lisel Koch. Metallwirtschaft (Ger.) **21**: 121 ('42). Effect of small addns. of aluminum on corrosion-resistance of zinc and zinc-copper alloys in atm. of water vapor at 95° C. studied. All alloys contained less than 0.006% of lead and studied in cast, cold-worked and annealed conditions. Found that aluminum content of more than 0.1% causes intercrystalline corrosion of alloys and that condition of alloys alters mode of attack but not deg. of corrosion. Addnl. expts. on super-pure zinc, free from lead, showed that small addns. of aluminum sufficient to cause intercrystalline corrosion.—*I.M.*

Corrosion of Galvanized Coatings and Zinc by Waters Containing Free Carbon Dioxide. L. Kenworthy & Myriam D. Smith. J. Inst. Metals **11**: 463 (Oct. '44). Purpose was to det. effect on corrosion rate of galvanized steel and zinc by separate and combined variations in hardness of water, free carbon dioxide and temp. Surface finish and compn. of zinc sheet had so little effect on rate of corrosion that only one grade (with clean rolled surface) used in later tests. *Cold Water:* Specimens 3×1.7 cm., cleaned with lime putty and degreased with acetone, suspended, in duplicate, vertically in 300 ml. of conductivity water, hard water and equal mixture of both. CO_2 varied by bubbling in carbon dioxide-air mixts. overnight, then maintg. same gas in ambient atmosphere. Specimens transferred to fresh flask, similarly prepd., every few days. Oxygen concn. always satd. at practically same value as when bubbling in pure oxygen, even with 5% CO_2 mixt. Zinc in soln. detd. with sodium diethyl-dithiocarbamate, and free CO_2 by titration with $N/20$ sodium carbonate, using phenolphthalein. Specimens cleaned for reweighing by 5% acetic acid; remaining coating removed for depth of pitting measurement by 5% sulfuric acid inhibited with 0.2% arsenious oxide. Total attack of zinc specimens increases with increasing CO_2, linearly in mixed water, but at decreasing rate in hard water. In conductivity water rate of attack accelerated with increasing CO_2. Zinc in soln. increased linearly with CO_2 in conductivity and mixed waters, and rate maintd. uniformly for over 240 days. In solns. low in CO_2, pitting penetrated much deeper than did general corrosion in much stronger concns. Zinc-iron alloys, contg. 4.8 and 7.7% iron, behaved similarly to zinc specimens, but their resistance to pitting greatly superior to pure zinc, thereby indicating protective value exceeding hot-dipped coatings, or electrogalvanized coatings where alloy entirely absent, for use in soft waters low in CO_2. With galvanized steel, although soln. rate of zinc similar to zinc plate in conductivity, water low in CO_2, galvanized plates pitted only about $\frac{1}{10}$ as deeply, but at sufficiently rapid rate to penetrate 0.5-oz.-per-sq.ft. coating in 46 days. When pits penetrate

outer zinc, exposing alloy layer and later basis metal, rate of penetration decreases because of lower soln. potential of exposed material, which becomes cathodic to zinc and causes pits to spread rather than to pierce. With low CO_2, rate of pitting exceeded rate of penetration by general attack at higher CO_2 concn. Time for first appearance of iron rust, marking life of coating, increased inversely as CO_2 in hard and mixed waters. Life of coating decreased linearly as thickness of outer zinc layer reduced; protection afforded by alloy layer negligible. At equal CO_2 content, conductivity water most corrosive; below 20 ppm. CO_2 hard water more corrosive than mixed water, but their positions reversed at higher concns. *Hot Water:* Premature rusting at cut edges of galvanized specimens prevented by Bakelite varnish dried at 135° C.; this proved resistant to stripping agents used. To minimize change in CO_2 during heating, flasks entirely filled with water and provided with small overflow funnel. CO_2 estd. in cold sample, before beginning tests. Otherwise essentially same methods used as for cold water. Flasks immersed in bath at 85° C. for 6 hr. daily, then allowed to cool overnight. Corrosion products removed in 5% acetic acid, by brushing, and cathodic cleaning in 10% potassium cyanide. Loose red rust spot on surface considered criterion of failure. Attack in all cases by pitting, generally at center of cup-like mound of corrosion products formed at base of gas bubbles. On zinc, hard-scale nodules formed additionally to bubble cups which increased with CO_2. On galvanized specimens amt. of scale and corrosion product appeared least in waters with high CO_2 content; centers of cups were darker than periphery indicating exposure of alloy layer. In absence of CO_2, amt. of zinc dissolved decreased with time, practically stopping in 30 days; for solns. contg. 20 ppm. or more CO_2, zinc in soln. increased nearly linearly with time. Corrosion of zinc exceeded that of galvanized steel, especially after 30 days. In hard water without CO_2, specimens did not rust in 191 days, and lasted nearly 100 days at 60 ppm. CO_2. Pitting of zinc generally much worse than galvanized specimens; depth of pitting greatest in water contg. 5.6 ppm. of free CO_2, apparently critical concn. In cold water presence of zinc coating estopped rusting of cut edges of galvanized specimens, whereas in hot water exposed steel edges rusted within 3 days; 50 to 80% of coating remained when *face* rusted. As final recommendations, hot-dipped coating, at least 2 oz. per sq.ft. on each side, comprising approx. equal proportions of outer zinc and subsurface alloy layer appears to provide reasonable protection in most circumstances. Reduction of CO_2, at least below 5 ppm., and hardness of 100 ppm. desirable.—*A. A. Hirsch.*

Corrosion of Condenser Tubes on Removing Incrustations From Them. I. S. KATSEN. Korroziya i Bor'ba s Nei. **7**: 3: 14 ('41). Deposits consisting of carbonates can be dissolved by HCl; some recommend addn. of inhibitor. Deposits consisting of silicates and sulfates can be softened by soda soln. Brass (70% Cu, 30% Zn) or admiralty brass (70% Cu, 29% Zn, 1% Sn) generally used in condenser tubes. Al increases corrosion resistance of brass. Fe and Mn addns. promote deleterious dezincification, while As, Sn, Ni, Al, and W useful in preventing it. Heat-treatment and residual stresses affect susceptibility to corrosion in some media; annealing at 250–300° usually recommended. Na hexametaphosphate solns. (50 mg./l.) did not increase corrosion of brass condenser tubes. Brass and admiralty brass noticeably corroded in 1, 2, 3 and 5% Na_2CO_3 solns. at 20, 50 and 75°. Amt. of corrosion increased with increasing temps. and concns. Tests made with acid cleaning solns., 3 and 5% HCl at 50 and 75°, and 5% H_2SO_4 at 50°. Effect of 0.5% inhibitor (no anal. given) detd. as well as effect of contact of brass with Fe. Brass not greatly attacked by acid solns. within 10 hr. Corrosion of brass decreased by contact with Fe, but Fe severely attacked by galvanic action. Use of inhibitor decreased corrosion of Fe. Fe plates in condenser can be completely protected by painting or lacquering and by use of inhibitors against attack by acids used to remove incrustations.—*C.A.*

Corrosion Prevention by Controlled Calcium Carbonate Scale. SHEPPARD T. POWELL, H. E. BACON & J. R. HILL. Ind. Eng. Chem. **37**: 842 ('45). Use of controlled $CaCO_3$ scale for corrosion prevention in cooling-tower systems serving steel equip. intensively investigated, owing to scarcity of Cu alloys. In past, failure has resulted because of ignoring of factors such as org. contaminants, dissolved solids, wrong chem. treatment, pptn. of finely divided $CaCO_3$ instead of scale, etc. If rising temps. cause actual pH of water to drop at same rate as $CaCO_3$ satn. pH, scales of uniform thickness will be

deposited over entire temp. range. Graphs presented which facilitate estn. of pH at higher temp., and also satn. index. When pH of water must be adjusted, sometimes better to use lime instead of NaOH or Na_2CO_3. In view of difficulty of detg. scale formation in actual heat exchanger, use of pilot heat exchanger using small pipe connected by unions suggested. Pipe specimens can be removed every week or two and tagged with record of water conditions producing given results.—*C.A.*

Scale and Corrosion Control in Potable Water Supplies at Army Posts. R. T. Hanlon, A. J. Steffen, G. A. Rohlich & L. H. Kessler. Ind. Eng. Chem. **37**: 724 ('45). Tests made on hot water systems supplying 6000 gpd. of water at 180°F. at one post having corrosive and scale-forming water supply. Com. conditioning agents used following procedures recommended by mfrs. Unadjusted org. material from plant juice (77 gal. per mil.gal. of water) did not prevent scale formation or corrosion. Mixt. of orthophosphate, pyrophosphate and org. matter from plant juices (75 ppm.) partially effective in preventing scale and generalized corrosion. Localized corrosion observed. Pyrophosphate (6 ppm.) did not prevent corrosion or deposition of scale. Mixts. of Ca and Na hexametaphosphate did not prevent pptn. of aragonite when used at rates of either 8.4 or 14.5 ppm. Some corrosion observed. Na hexametaphosphate (4.4 ppm.) inhibited scale formation somewhat, but did not inhibit corrosion as well. Polyphosphate and Na silicate (14.5 ppm.) did not inhibit corrosion or scale formation. Na silicate (64 ppm.) and mixt. of Ca and Na hexametaphosphate (4.9 ppm.) inhibited scale formation and gave reasonable protection against corrosion. Na silicate (4.8 ppm.) and Na hexametaphosphate (4.8 ppm.) fed from single proportioning device precluded formation of aragonite scale and prevented all but localized corrosion. Na septaphosphate (7.9 ppm.) prevented scale formation and gave substantial protection against corrosion. All chems., except unadjusted org. material, gave equally good results on heaters supplying 2500 gpd. of water at 140° F. Detailed description of methods of water conditioning at 30 army posts, with anals. of water, presented. Threshold conditioning used to control scale, and chem. conditioning gave effective corrosion control.—*C.A.*

Turbine Deposits Removed by NaOH. V. Walker. Elec. Times **104**: 774 ('43). Removal of deposits contg. high percentage of SiO_2 effected by introducing 10% aq. NaOH at rate of 2 gpm. until condensate alk. (phenolphthalein). During this period turbine speed of 200–300 rpm. maintd. Stop-valve closed and after turbine had come to rest NaOH allowed to react with deposits for about 15 min. Procedure repeated 8 times, after which rotor washed with condensate at 2 gpm. until cond. of effluent normal. Treatment resulted in increase in max. load obtainable from 27,000 to 33,000 kw. Precautions for protection of instruments, glands and valve packing during treatment given.—*C.A.*

Soluble Inhibitors. U. R. Evans. Ind. Eng. Chem. **37**: 703 ('45). If immediate corrosion product sparingly sol., attack likely to be stifled. If immediate product sol. but secondary product only sparingly sol., attack will continue. Anodic inhibitors function by forming sparingly sol. anodic product. If corrosion under cathodic control, anodic inhibitors, such as NaOH, Na_2CO_3, Na_2SiO_3, Na_3PO_4, and chromates likely to be dangerous, since localized but intensified attack may result if they are added in insufficient concn. If H_2O contains chlorides, intensified attack will occur at much higher concns. of inhibitor. Cathodic inhibitors form sparingly sol. products on cathode areas. Cathodic inhibitors, such as Zn salts, and Ca bicarbonate safe as they do not normally lead to intensified attack but generally less efficient in reducing total corrosion than anodic inhibitors.—*C.A.*

Zinc, Manganese and Chromium Salts as Corrosion Inhibitors. R. S. Thornhill. Ind. Eng. Chem. **37**: 706 ('45). Sulfates of Zn, Mn and Cr (chrome alum) added to tap H_2O and tap H_2O with addnl. CO_2. Similar tests made with $CrCl_3$ in tap H_2O and 0.033–1 molar NaCl solns. Molar concns. of inhibitors ranged from 0.00033 to 0.010. Corrosion tests indicated that Zn and Mn reduced corrosion of steel to about 20–30%. $ZnSO_4$ more efficient inhibitor than Mn but it caused marked intensification along water-line zone. Mn salts free from this defect. Chromic salts brought about certain measure of inhibition at low but not at high concns. High concns. of Cr also caused intensified water-line attack. Therefore, both Zn and Cr salts must under some circumstances be regarded as dangerous inhibitors.—*C.A.*

Sodium Nitrite as Corrosion Inhibitor for Water. A. WACHTER. Ind. Eng. Chem. **37**: 749 ('45). $NaNO_2$ good corrosion inhibitor for H_2O and often can completely suppress corrosion of steel. Concns. needed for inhibition vary with severity of conditions, pH and compn. of H_2O. 0.005% suffices for distd. H_2O, 0.03% for 0.05% NaCl soln., 4% for 3% NaCl soln., and 0.06% for H_2O from gasoline pipeline. pH has marked influence on corrosion only in range 6–10 when insufficient $NaNO_2$ present. However, in general, max. effectiveness achieved in alk. solns. $NaNO_2$ also effective on scaled steel. It inhibits corrosion of steel in aq. iso-PrOH and aq. MeOH. Corrosion of various brasses, of 70% Cu-30% Ni, of monel, of Ni, of Al, of steel contg. 18% Cr and 8% Ni, of steel contg. 13% Cr, and of Sn-plated steel in tap H_2O and/or 0.05–0.1% NaCl solns. either inhibited or not adversely affected by $NaNO_2$.—*C.A.*

Galvanic Corrosion of Steel Coupled to Nickel. Effect of Chromate and Lime Additions to Water. H. R. COPSON. Ind. Eng. Chem. **37**: 721 ('45). With 3 to 1 area ratio of Ni to steel, galvanic corrosion of steel appreciable but not excessive in Bayonne tap H_2O. Ni specimens scarcely affected. Lime did not seem suitable as inhibiting agent when added to give pH of 11. While it cut down total galvanic effects, it also localized corrosion so max. rate of penetration increased. Addn. of 300 ppm. of Na chromate to H_2O effectively made steel more noble and inhibited corrosion if steel rubbed once in while. Otherwise pitting developed. In intended service, movement in slot of canal lock would be expected to provide sufficient rubbing. Since canal H_2O in service would be stagnant and replaced only at infrequent intervals, use of inhibitor seemed practical.—*C.A.*

Chromate Corrosion Inhibitors in Bimetallic Systems—Technology Under Conditions Encountered in Practice. MARC DARRIN. Ind. Eng. Chem. **37**: 741 ('45). Chromate effective for combating bimetallic corrosion in recirculating and quiescent H_2O systems. It inhibits by anodic polarization; at times it forms visible coating contg. hydrous trivalent oxides of Fe and Cr. No satisfactory substitute for exposure tests. Generally 6 mo. sufficient to predict behavior of bimetallic system in H_2O at normal temp. Temps. should be same as in service; if there is fluctuating temp., safe to figure on concn. required to inhibit at highest temp. Although aeration greatly stimulates most corrosion, it has practically no effect when sufficient chromate present unless it causes entry of acidic or reducing substances. Chromate does not protect partially submerged panel at or just above H_2O line; at very low concns. chromate may stimulate corrosion of Fe. Generally hexavalent Cr as chromate little more effective than as dichromate. pH variations from 7.0 to 9.5 unimportant. Chromate may be assisted by cathodic inhibitors. Small addns. of metasilicate with chromate beneficial for systems contg. Al. For Fe in tap H_2O at 70° F., 500 ppm. ample to initiate inhibition. No harm results from excess chromate nor is there increased consumption. Although concn. required to inhibit independent of area of metal surface it is protecting, rate of consumption function of metal area as well as concn. Consumption also increased by rise in temp., lowering of pH below 7.0 or by presence of reducing substances. Where there is exposed cathodic metal, such as brass, fairly high concn. of chromate required to protect Fe, especially if there are stagnant regions or old rust accumulations. Under some conditions, as in rapidly moving stream not subject to local depletions of chromate, much lower concns. can be used. Practical applications described for air-conditioning systems, refrigeration brines, automobile systems, diesel engines, power rectifiers and other systems. Recommended value for $CaCl_2$ brine 1750 ppm. chromate and for NaCl brine 3500 ppm. Large users prefer Na dichromate plus caustic soda rather than Na chromate because of lower cost and com. availability of dichromate.—*C.A.*

Threshold Treatment of Water Systems—Corrosion Control and Scale Prevention With Glassy Phosphate. G. B. HATCH & OWEN RICE. Ind. Eng. Chem. **37**: 710 ('45). Corrosion and deposition of Ca carbonate and Fe oxide in H_2O systems can be controlled by very low concns. of molecularly dehydrated phosphates (Calgon). For prevention of scale, max. eff. obtained by 2 ppm. Calgon in H_2O. As temp. increases, concn. of $Ca(HCO_3)_2$ that can be maintd. without deposition decreases both for treated and untreated H_2O. Prevention of $CaCO_3$ deposition by Calgon apparently results from

stabilization of condition of supersatn. with respect to $CaCO_3$. For prevention of Fe deposition, phosphate must be added before Fe-bearing H_2O exposed to air or Cl. Ratio of Calgon to Fe of 2 to 1 generally required. When threshold treated H_2O passed over metal surfaces, protective films formed at rate depending on supply of Calgon to metal surface. Film does not disappear rapidly upon discontinuance of treatment nor is it affected by pH values of 5 or over. Efficacy not appreciably altered by presence of Cu couples. Calgon also effective in NaCl or $CaCl_2$ brines. Adsorption of Calgon on solid surfaces plays important role in all applications of threshold treatment.—*C.A.*

Corrosion Control With Threshold Treatment—Factors in Formation of Protective Films Upon Steel by Waters Treated With Glassy Phosphates. G. B. HATCH & OWEN RICE. Ind. Eng. Chem. **37**: 752 ('45). Continuous flow tests made both with variable and const. volumetric flow rates. They showed rate of formation of protective films upon metal surfaces in threshold treated H_2O was function of rate of supply of glassy phosphate (Calgon) to these surfaces and was dependent upon type and veloc. of flow. Two types of small vol. batch tests designed to provide adequate motion of liquid relative to metal surface by mech. agitation or aeration tested and found to yield results amenable to same interpretations as those from continuous flow tests. However, concn. of Calgon required to form protective film considerably greater when soln. vols. small as in batch tests than in continuous flow tests. Furthermore, inhibitor lost by adsorption on rust unless protective film formed rapidly. Effect of protective film persisted for appreciable time, after treatment discontinued, but if film not completely formed before periods of quiescence its further rate of development slower than if agitation continued. Effect of temp. similar in treated and untreated H_2O except that max. wt. loss shifted from 80 to 60°. Cu couples did not alter inhibitive action but more Calgon required. Brines needed more rapid supply of Calgon than did tap H_2O. Effect of concn. of Calgon on corrosion attributed to fact that in dil. solns. Calgon present as Ca complex while in concd. solns. excess of free Na salt which attacked metal. Addn. of Ca in ratio of Ca to Calgon of 0.2 gave max. protection with 1% Calgon soln. With few exceptions, Ca concns. present in H_2O high enough to insure max. eff. of inhibitor. Nevertheless, batch procedures not applicable to all types of H_2O. Min. inhibitor concn. required in practice best found by actual trial.—*C.A.*

Protection of Small Water Systems From Corrosion. WILLIAM STERICKER. Ind. Eng. Chem. **37**: 716 ('45). Life of piping and plumbing fixtures can be greatly increased by addn. of small amts. of Na silicates to H_2O. Hot H_2O can be treated by passing small part of it over $Na_2O:3.3\ SiO_2$ glass. Cold H_2O must be treated with soln. of Na silicate. Generally 38% soln. of $Na_2O:3.3SiO_2$ recommended. Usually min. dosage to give good deg. of inhibition equiv. to 8 ppm. SiO_2. After protective film formed, it can be maintd. by less silicate but at least 4 ppm. residual SiO_2 generally necessary. Larger amts. required if considerable amts. of chlorides present. If pH above 6, preferred silicate $Na_2O:3.3SiO_2$; if pH 6 or below, $Na_2O:2.1SiO_2$. Various feeding devices have been used for adding liquids to H_2O. Laundries have found such treatment of value with zeolite-softened H_2O. They generally use silicate soln. which will treat both hot and cold H_2O. Although reported earlier that silicate treatment could be used only in short piping systems, recent results have shown no limitation on distance to which silicate will carry when fed as soln. Lab. tests do not always check field data probably because of factors not yet considered or recognized. Actual field tests show improved conditions with steel after 17 yr. Yellow brass also protected.—*C.A.*

Corrosion Control in Potable Water System. ROLF ELIASSEN. W. W. & Sew. **92**: 187 ('45). Various methods of approach to corrosion control briefly reviewed and results of field experiences at army posts summarized. Porous nature of carbonate coatings permits severe pitting underneath, more particularly in hot water systems. Formation of protective films with Na silicate or polyphosphates, while not completely perfect, reduces rate of corrosion considerably. Na silicate having compn. 1 $Na_2O:3.25SiO_2$ initially dosed at 12 to 16 ppm., as SiO_2; this gradually reduces feed until ends of system show 1 ppm. SiO_2 above normal. If pH of treated water below 8.0, more alkaline silicate, such as 1 Na_2O: $2SiO_2$, used. Sodium hexametaphosphate $(NaPO_3)_6$, said to form directly adsorbed

film, must be fed in quant. to replace losses from metal through reversion to orthophosphate. Feeding initiated at 6 to 12 ppm., and reduced, with time, to allow residual of 0.5 ppm. Final dose may be about 2 ppm. for cold water, and 6 ppm. or more in hot water lines. Absence of red water no criterion of protection, as polyphosphates combine with ferrous ion to form complex; this masks corrosion. Sodium septaphosphate, $Na_9P_7O_{22}$, has properties similar to those of hexametaphosphate. Tetrasodium pyrophosphate, $Na_4P_2O_7$, has been used successfully for corrosion control. Combination treatments of polyphosphates and silicate desirable when water tends to scale if silicate used alone. Feeding should be through proportioning devices. Test loops of piping for periodical observation provide most accurate means for checking results.—*C.A.*

Advantages of Chlorinated Rubber for the Treatment of Concrete Walls and Floors. ANON. Wtr. & Wtr. Eng. (Br.) **48**: 412 (July '45). Chlorinated rubber, or "Detel," dissolved in org. solvent. By painting on almost any surface it forms tenacious, nonporous, non-inflammable and non-poisonous film which resists corrosion and deleterious influences. It is applied like paint. Important application is treatment of concrete. —*H. E. Babbitt.*

For Shafts and Submerged Structures. K. STANGELAND & L. MCWILLIAMS. Metco News **3**: 1: 2 (Nov.–Dec. '44). Large hydr. power plant of Shawinigan Water & Power Co. at La Gabelle equipped with considerable no. of submerged steel structures, such as sluice gates on dam and head gates and racks of main units. In 20-odd yr. that this station has been in operation, considerable time and money expended to maint. these structures and limit corrosive action by repainting surfaces at intervals. Experience has shown that paint coatings will protect these structures for only short time. Maint. schedule has been 4–5 yr. for outdoor and 8–10 yr. for indoor structures. On outdoor structures, ice condition during winter causes wear and scaling of painted surfaces. Have been cases where paint started to scale during first winter. For this reason and to reduce maint. cost, need for permanent anti-corrosive coating of structures recognized. Starting few yr. ago, no. of these structures reconditioned by metallizing zinc coating about $\frac{10}{1000}$ in. thick. Procedure followed for this type of metallizing is: Structure lifted and left to dry, and necessary scaffolds erected. In case of indoor structures, desirable to elim. dirt and dust in bldg. by having cleaning and metallizing done outdoors. Accomplished by utilizing railway flatcar, and work done out on railway trestle. One of photos shows head gate measuring $16' \times 30'$ mounted on flatcar. Surface prepn. done by sandblasting, and sand obtained from nearby pit. Moisture removed before sand delivered to sandblasting machine. To clean avg. surface for metallizing, 1 cu.yd. sand required per 100 sq.ft. of surface. Sandblasting machine made by Rumelin Mfg. Co., Milwaukee, and operates at 100 lb. per sq.in. air pressure. Blast nozzles with $\frac{3}{8}''$ to $\frac{1}{2}''$ diam. opening have given best results. Care taken to metallize surface immediately after cleaning, as surfaces cleaned by sandblasting will rust when exposed to atm. for very long. Two men working together can clean and metallize 100 sq.ft. per 8-hr. day. Avg. total cost for zinc metallizing 40¢ per sq.ft. Following gives breakdown of cost for zinc-metallizing 1100 sq.ft. of No. 4 sluice gates:

Material	
Sand: 13 cu.yd. @ $1	$ 13.00
Metco Zinc: 525 lb. @ 39¢	204.75
Miscellaneous	30.00
TOTAL	247.75
Labor	
Screening and drying sand	19.20
Sandblasting	102.20
Metallizing	49.30
Rigging, scaffolds, etc.	20.00
TOTAL	190.70
TOTAL MATERIAL AND LABOR	$438.45

Some 10 yr. ago zinc metallizing job done on outdoor sluice gate at Shawinigan Falls. Metallized surface of this gate still in excellent condition. No wear or deterioration of zinc coating indicated.—*Ed.*

Use and Misuse of the Salt Spray Test as Applied to Electro-Deposited Metallic Finishes. C. H. SAMPLE. A.S.T.M. Bul. *No.* 123: 19 (Aug. '43). When exposing suitable specimens to brine mist to test relative corrosion resistance of coatings, results not generally reproducible nor suitably corre-

lated with actual service behavior. Since govt. specifications incorporate salt spray tests, inadvertent increase in its use forced. Inclusion in A.S.T.M. tentative specifications covering nickel-chromium and copper-nickel-chromium coatings on steel and zinc, resp., is to reveal continuity of coatings. The greater the potential between coating and basis metal in salt spray chamber, the greater the corrosiveness. Indicator function fails if potential difference reversed so that coating electro-pos. to base, but test may still roughly measure thickness of coating. Thorough standardization and correlation with performance necessary for proper evaluation. Time for "first rust" to appear not so important as condition of coating after given exposure. *Discussion. Ibid.* SAM TOUR: Questions desirability of ironclad and complete uniformity of test since service conditions variable. F. L. LA QUE: Since salt spray test purely arbitrary one, should be standardized. C. E. HEUSSNER: Salt spray segregates inferior electro-deposited coatings, but satisfactory product in salt spray chamber not necessarily qual. deposit. E. A. ANDERSON: In same type samples, order of qual. in salt spray may widely mislead judgment of behavior in service.—*A. A. Hirsch.*

Cause of and Remedy for Pitting and Corrosion of Locomotive Boiler Tubes and Sheets, With Special Reference to Status of Embrittlement Investigation. R. E. COUGHLAN ET AL. Am. Ry. Engr. Assn. **45**: 441: 47 (Nov. '43). Progress report. No new development.—*R. C. Bardwell.*

Water Re-utilization—Its Status During the War. WESCHKE. Centr. Zuckerind. (Ger.) **51**: 5 ('43); Chem. Zentr. (Ger.) **I**: 2151 ('43); C.A. **37**: 5532. Corrosive action of diffusion and press waters chief obstacle to their re-utilization. Galacturonic, acetic and formic acids formed by decompn. of pectin materials, not fermentation, considered responsible for corrosion. Corrosion can be avoided by sterilization of re-utilized water by heating, chlorinating and other chem. treatments and by use of corrosion-resistant materials, e.g., Cr steel. Conversion of sugar industry to water re-utilization unlikely.—*C.A.*

Corrosion and Incrustation of an Enameled Pipe Carrying Thermal Water. Z. Ver. deut. Ing. (Ger.) **88**: 29 ('44). Corrosion and incrustation in pipe, 7 km. long, which conveys thermal water from spring to spa, observed. Pipe laid about 30 yr. ago lined with enamel. Mineral water soft and contains fairly large amts. of oxygen and of radium emanation. pH value of water about 7.8 and should therefore not be corrosive. Enamel lining has, however, almost disappeared along whole length of pipe and under thick incrustation deep pits have appeared. Capac. of pipe has been reduced by about 20 to 25%. As it is not possible for tech. reasons to clean pipe mechanically or with acids, it must be replaced by pipe of some material resistant to corrosion, such as glass, porcelain or Eternit. —*W.P.R.*

Correct Stabilizing Treatment Plus Tailored Control to Eliminate Scale in Water-Cooling Systems. W. H. THOMPSON & J. W. RYZNAR. Oil Gas J. **42**: 19: 43 ('43). Concn. ratio of make-up H_2O to circulating H_2O requires careful control. Stabilizing chems. necessary and pretreatment before stabilization may be needed if make-up H_2O high in concn. or if it is markedly scale-forming in character. Pretreatment can be effected by pptn. followed by settling, by zeolite softening or by acidification to convert bicarbonate into sulfate. Processes discussed in detail.—*C.A.*

Corrosion in the Refrigerating Industry and Its Control. A. STEINBACH. Gesundh.-Ing. (Ger.) **67**: 67 ('44). Types of corrosion which occur in refrigerating plants described. Most frequent type general corrosion due to galvanic action set up when refrigerating brine comes into contact with several different metals or alloys. If anodic surface large in comparison with cathodic surface, amt. of corrosion not serious. Surfaces liable to corrosion can be protected by special paints. Particularly serious type of corrosion is that occurring at level of brine in tanks and pipes. Fluctuating level causes alternate wetting and drying of metal surface. Deposits of salt cause pitting. Corrosion reduced when brine kept free from particles of dirt and rust. Brine should be made of pure salt and should have pH value between 8 and 9. Brines of calcium chloride or magnesium chloride less corrosive than sodium chloride. Brines tend to become acid by absorption of oxygen and carbon dioxide; entry of these gases must be prevented or they must be removed from soln. Pitting occurs not only in parts of plant in contact with brine but also in cooling-water tubes of condensers. Causes and mechanism of formation of pits discussed. Best method of preventing pitting caused by

formation of local elements is application of several coats of paint or of zinc or lead. Where pitting due to presence of oxygen or carbon dioxide in water, these gases must be removed. Contact corrosion may occur where 2 dissimilar substances in contact; liquid entering crack between them removed from general circulation with result that amt. of oxygen coming into contact with walls of crack reduced, and in case of metals, protective skin of metallic oxide not formed. This type of corrosion occurs at riveted seams of tanks and in neighborhood of screws. Expt. described in which strips of metal coated with lead and bent at both ends screwed at ends to strips of clean steel, steel covered by 2 coats of paint, galvanized metal, zinc, copper, wood and glazed cardboard. In addn. strip of metal coated with lead and painted screwed to painted steel strip. All strips alternately immersed and removed from 20% soln. of sodium chloride at intervals of about 10 min. for 3 yr. Zinc strip disappeared completely during this period. Lead-coated strip in contact with copper strip considerably corroded. Contact corrosion had occurred but overshadowed by results of galvanic action. Contact corrosion could be clearly seen in lead-coated strips in contact with wood or cardboard. Many small pits visible in lead coating, particularly at ends, whereas middles of strips uncorroded. Pits penetrated through lead coating to metal beneath. Best method of preventing contact corrosion is insertion between 2 pieces of metal of joint of plastic material sufficiently elastic to fill gap completely and of type completely impermeable to water. Intercrystalline corrosion occurs in refrigerating plants mainly in cast-iron structures such as brine pumps but also in steel. Only method of preventing this type of corrosion is by use of resistant metals. Corrosion also caused by stray currents from elec. motors and generators at refrigerating plant; this can be overcome by earthing elec. equip. More difficult to control corrosion due to stray currents originating outside plant. Corrosion of welded seams also discussed.—*W.P.R.*

Unusual Corrosion Difficulties and Their Solution. F. Alton. Eng. & Boiler House Rev. (Br.) **57**: 166 ('43). Review given of investigations into causes of corrosion in certain German power plants. Corrosion of jet condenser caused by thermo-elec. action set up by difference in temp. of various parts of condenser. Corrosion of feed pump brought about by electrolytic action between iron and small quants. of copper deposited from feedwater. Corrosion of manganese-steel impellers can be prevented if sodium thiosulfate used instead of sodium sulfite for removal of oxygen. Control of corrosion due to copper and to carbon dioxide also discussed. *Op. cit. Ibid.* **57**: 211 ('43). Corrosion of pumps for boiler feedwater, due to presence of copper in water, can be prevented by maintg. pH value above 7.5 by addn. of ammonia. Corrosion due to copper can also be prevented by adding sodium hydrosulfite to water to remove oxygen. In h-p. steam plants operating on condensate free from oxygen but contg. small amts. of CO_2 which reduce pH value to about 4, corrosion can be prevented by addn. of ammonium salts or gaseous ammonia; where feedwater chemically treated, use of ammonium salts preferred.—*W.P.R.*

Postwar Building Studies No. 13. Non-ferrous Metals. Com. Convened by British Non-Ferrous Metals Research Assn. H.M. Stationery Office, London ('44). 72 pp. Report of com. convened by British Non-Ferrous Metals Research Assn. at invitation of Ministry of Works. In first part of report general properties, including resistance to corrosion, of non-ferrous metals and their alloys described in relation to their use in bldg. In second part specific uses of metals described. Recommendations for revision of present practice and suggestions for future investigations given in third part. Resistance to corrosion of such importance in bldg. that choice of metal or alloy often detd. by this factor; metal may have to resist corrosion in air, water and soil, corrosion due to stray elec. currents and galvanic corrosion. Prediction of corrosive character of water from its compn. difficult but certain general principles have been estd. Soft waters usually more corrosive than waters with high temporary hardness; this is particularly true of galvanized iron and steel but not true of aluminum. High concns. of sulfate and chloride nearly always increase corrosion. Carbon dioxide in concns. greater than 20 ppm. and high concns. of acid generally increase corrosion. Effect of chlorination of water on corrosion debatable but there is no evidence that corrosion is increased by chlorine in concns. usually present in tap water, i.e., less than 1 ppm. Resistance of alumi-

num to corrosion mainly due to formation of thin film of oxide on surface of metal; this film can be increased in thickness by anodizing or by other non-electrolytic processes. In normal circumstances wrought aluminum corrodes fairly rapidly in tap water. Cases of corrosion of aluminum in water contg. high concns. of carbon dioxide and chlorine have been reported from Germany. No information on behavior of aluminum alloys in contact with sewage and waste waters in domestic installations but aluminum alloys have proved satisfactory at sewage works; not attacked by ammonia, sulfur, asphalt or bitumen. Concrete, plaster and wood in contact with aluminum do not cause corrosion unless they are damp. Corrosion of aluminum in soil due to stray elec. currents takes form of pitting. Copper and its alloys, such as brass and gunmetal, generally resistant to corrosion. Copper may be attacked by very acid waters, particularly when copper installation new. Water contg. small amts. of copper may stain soap green. If water contained enough copper to make it unwholesome it would be unpalatable and green staining would be very pronounced. Corrosion of solder in soldered copper joints occurs occasionally, particularly in water contg. high concns. of chloride. Lead not corroded by most tap waters but small amts. of lead may be dissolved by water; waters which are soft and acid, or hard waters contg. high concns. of free carbon dioxide and chloride, plumbosolvent. Lead is cumulative poison and not detected in water by consumer; generally considered that 0.5 ppm. max. concn. of lead which can be tolerated. Fresh cement mortar, concrete and certain timbers can attack lead, particularly under damp conditions. Lead also attacked by acid soils. Nickel alloys, particularly Monel and Inconel, and stainless steel very resistant to corrosion by tap water. Galvanized materials fairly resistant to corrosion by water but may be attacked by wet steam and by soft waters contg. much free carbon dioxide. Effect of hot water on galvanized steel different from that of cold water. Effect of soft, acid water more pronounced when water hot. Overheating of metal and contact of foreign matter with galvanized surface may also cause corrosion of galvanized steel. Zinc slightly corroded by cement contg. much free lime and by mortar which has not set; not attacked by mortar after it has set, even when mortar is wet. Corrosion of zinc increased by contact of zinc with other metals, particularly copper. Timber may also cause zinc to be attacked. Zinc and galvanized metals attacked by very acid and very alk. soils, particularly when chlorides present. Use of non-ferrous metals in bldgs., including their use for pipes, tanks, boilers and other plumbing fixtures, discussed.—*W.P.R.*

POSTWAR PLANNING

A Master Plan for Water and Sanitary Sewer Utilities, Dallas, Texas. 40-page report by Homer A. Hunter, Supt., Dallas Water Dept., covering long-range development of water and san. sewer utils. to serve Dallas metropolitan area in '70 when, according to Bartholomew Master Plan for Dallas, pop. estd. to be 667,000. '44 pop. served by Dallas water supply system 425,000. These improvements call for expenditure of $20,964,000 for water supply system and $15,752,000 for sewerage system, total of $36,716,000. In middle '30's constr. and operation of sewerage system made function of water dept., hence inclusion of these improvements in report. Detailed plans and specifications for work costing $956,600 complete and engrs. employed to design addn. to treatment plant costing $750,000. Thus, considerable amt. of work will be ready for BUILD NOW stage when it arrives. Financing of 25-yr. program will be largely from revenue. $10,500,000 bonds required will be so issued that in '70 they will all have been retired and dept. will be on pay-as-you-go basis. **Water Supply System:** In '82 Dallas acquired privately-owned water supply system originally installed in early '70's. Development of various sources kept pace with growth of city, culminating in building of Lake Dallas and Bachman St. treatment plant in '30. Other supplies abandoned, although White Rock Lake, now used for recreational purposes, may be drawn upon in emergency. Dallas Water System serves city of Dallas and 9 communities supplied with water in bulk. '44 consumption was 37.7 mgd. with peak day of 72.0 mil.gal., as compared with 30.6

mgd. and 62.0 mgd., resp., for '42. *Lake Dallas:* Impounding reservoir on Elm Fork of Trinity R. 30 mi. north of Dallas. Drainage area 1100 sq.mi., spillway area 10,000 acres. Hydr. fill dam 14,000′ long with 15′ free board above concrete spillway. Emergency spillway 5′ higher than main spillway. Water flows in river channel to treatment plant. Original capac. 63,000 mil.gal. with estd. yield of 88 mgd. Silting and transmission losses reduce this to present yield of 70 mgd. at Bachman St. treatment plant and pumping station. *Bachman Street Station:* Rated capac. of 24 rapid sand filters is 50 mgd. Plant functions well and has handled rates of 75 mgd. Auxiliaries fairly well balanced but plant 15 yr. old and needs modernization. Filtered water storage of 5 mil.gal. inadequate. Four electric-driven raw water pumps of 90 mgd.-capac. deliver water to plant, while 6 electric-driven pumps of 75-mgd. capac. deliver filtered water to distr. system divided into 4 pressure dists. as follows: (1) East Low—Down town, South Dallas and supply to East High and several smaller repumpage dists.; storage 22 mil.gal. underground. Three communities with 7 stations draw water from this dist. (2) East High—Two repumpage stations, 5 pumps, 17.3 mgd.; with elevated storage of 4 mil.gal., but only 25% fully effective due to elevation. (3) West Low—Most of commercial area of Oak Cliff, much of residential area and supply to West High; storage 5 mil.gal. underground. (4) West High—One repumpage station, four pumps, 14.5 mgd.; elevated storage of 3 mil.gal. All water mains 4″ and larger cast iron, smaller mains galvanized steel or wrought iron. Copper services in use for 20 yr. Metered water 85% of water pumped. Improvement to system during 25-yr. period has been studied in connection with master plan's estd. growth of dist. and based on carefully financed program. These improvements briefly summarized as follows: (1) Immediate expansion and modernization of Bachman treatment plant and pumping station to capac. of 100 mgd. at estd. cost of **$775,000.** Work involves constr. of 8 filter units; revise washwater system; build new pre-treatment basin and install mech. chem. mixing, flocculation and cleaning devices in this and 2 existing basins; build chemical storage building with modern handling equipment; build 5-mil.gal. filtered water basins; remodel filter and lab.; install two 30-mgd. low-lift pumps, one 20-mgd. high-lift pump and replace 5 existing pumps to meet existing head conditions; also instal. low- and high-head pump for standby service. (2) By '52 revamped 100-mgd. Bachman St. Station will require reinforcement. Proposed to construct new treatment and pumping station on Elm Fork, probably in town of Letot. Initial capac. of 50 mgd. will cost about **$1,500,000,** and with Bachman St. Station will serve until about '70. Proposed to plan this station so that 50-mgd. addn. can be easily added. (3) Safe yield of Lake Dallas will be reached in '63. Consequently, in '59 proposed to start work on Denton Creek, branch of Elm Fork, with safe yield of 71 mgd. at cost of **$6,700,000.** This reservoir with Lake Dallas will serve until many years after '70. (4) Progressively from '46 to '50 addnl. storage including 20-mil.gal. and 5-mil.gal. reservoir; two 2-mil.gal. and one 1.5-mil.gal. tanks will be added to distr. system at cost of **$650,000.** Likewise, during this period, 7 pumps with total capac. of 56 mgd. and costing **$55,000** will be installed in repumpage stations. (5) Progressively as the growth of city demands and as foregoing major items will require, improvements to distr. system will be made. Work is summarized as follows: (a) new supply and feeder mains, **$2,859,000;** (b) replacing small mains, renewal and revamping of existing mains, **$750,000;** (c) minor distributor mains, services, etc., **$7,705,000.** **Sanitary Sewerage System:** Original sewage treatment plant built in '19, enlarged in '23 and modernized in '40, consists of primary settling tanks, trickling filters, secondary settling tanks and separate sludge digesting tanks. Normal capac. of '40 plant 35 mgd. Plant flexible and actual operations indicate higher capac. for many units and it may be enlarged at nominal cost as needs arise. Sewage collected and pumped to treatment plant at two 3-pump stations with capacs. of 25.3 mgd. and 50 mgd. Many large sewers badly overloaded and must be reconstructed as soon as possible. In '30 long-range plan for sewer constr. formulated and has been followed, but too little rehabilitation work done. Expected that '30 plan will be followed in future improvement of sewerage system. Contemplated improvement of system involves following items: (1) Immediate duplication of sludge digestion tanks at cost of **$125,000.** (2) In '56 treatment plant must be enlarged to 60-mgd. capac. at cost of **$750,000.** (3) Immediate installation of 2 pumps with total capac. of 25 mgd. in Cadiz

St. Station at cost of **$25,000. In '52, 3** existing pumps to be replaced at cost of **$50,000.** Expected that this station will be abandoned in '64 and all sewage pumped at Fair Park Station. (4) Small expenditures for new pumps will suffice until '64 when station will be enlarged at cost of **$125,000** to handle all sewage, as noted above. (5) Constr. of main truck sewers costing **$10,752,000** scheduled as needed throughout 25-yr. period. (6) Sum of **$4,325,000** included for small sewers, minor extensions and house connections. **Financial:** As stated above, improvements so scheduled that only 28% will require bond issues. Also, this "bond money" so distributed that all bonds will be retired by '70. Water works dept. operates under ordinance whereby persons desiring water and sewerage service required to participate in cost of main and sewer; likewise, cost of sewer laterals and services borne by consumer. Revenue from these sources estd. to be **$4,560,000.** This leaves some **$20,000,000** worth of improvements to be financed from operating surplus. Expected that water and sewer service rate schedules now in effect will not be changed so as to affect materially income from operations. Possibility that Trinity R. Improvement Program of the federal govt. may result in constr. of new reservoir as part of project prior to time of its need by city, with consequent saving in city funds. Long-range plan conservative both as to constr. and financing. Water dept. now on sound financial basis and can be kept so if this plan followed. By '70 first cost of water and sewerage util. will have reached **$60,000,000.** After '70, when util. becomes debt free, will be possible to take care of wear and tear and obsolescence by adequate depreciation reserves, and to pay cash for such improvements as may be necessary.—*O. R. Elting.*

Preplanning for Major Emergencies. T. H. Haines. Edison Elec. Inst. Bul. **13**: 3: 57 (Mar. '45). Boston Edison Co. inaugurates system of operating routines for major emergencies and hurricane damage. Requirement of emergency measures accentuated by hurricane of Sept. 21, '38, during which 292,000 customers of 400,000 out of service on night of hurricane; 1 day later 172,000 still without service and 2 wk. required before normal operation restored. Emergency organization proved its worth in storm of Sept. 14–15, '44, when only 184,000 of 400,000 customers suffered interruptions of service, many momentary or of short duration only; complete restoration of service accomplished by third day. Two factors of prime importance considered in setting up of plan: (1) It should be sufficiently comprehensive to provide adequately for organizing and supervising all activities likely to be necessary during any type of emergency imaginable. (2) It should be flexible in order that each major unit may function independently, or in conjunction with other units of emergency organization or with indirectly affected departments carrying on normal routine activities. Plan sets up Emergency Administrator assisted by staff composed of coordinators for: Public Relations and Publicity; Acctg. Procedure; Restoration Planning; Personnel; Federal, State and Munic. Contacts; Communication; Supplies and Transportation; Dispatching Labor, Supplies and Transportation; and Supt. of Affected Operating Dept. When emergency conditions prevail, president declares state of emergency and delegates complete authority to the Emergency Administrator and his staff. As example of operation of plan, many hours before hurricane of Sept. 14, '44, struck, assignments given all employees whose services could be utilized and they were requested to stand by at end of their shifts; tree expert companies and regularly employed contractors notified to expand their forces and instructed to report at specified locations; addnl. trucks equipped for tree clearing work; and all equip. serviced for emergency duty. Prelim. surveys and ests. of material requirements and available substitutes made and arrangements completed to secure needed quants. immediately. Arrangements also made with several utility companies outside path of approaching storm for necessary aid they might furnish. Course of storm followed by communication with util. and federal agencies having pertinent information. Duties and responsibilities of various coordinators described briefly: (1) *Public Relations and Publicity:* Representative set up in each city and town to handle all inquiries regarding service outage; det. priorities for restoration; news releases to local newspapers; take photographs and report conditions to headquarters. (2) *Federal, State and Munic. Contacts:* Provide police and military protection through aid of army service command, state guard and munic. depts. including police. (3) *Emergency Acctg.:* Issue uniform instructions on emergency acctg. procedures to all

clerical personnel; prepare and deliver emergency payroll. (4) *Communication:* Maint. and repair communication between key points of system under worst conditions imaginable; operate 2-way radio telephone system consisting of 23 mobile units, main station, and 8 sets at generating stations. (5) *Restoration Planning:* Speed of restoration detd. and regulated; survey damage and report nature, location and amt.; establish service priorities, order of importance being hospitals, fire stations, telephone exchanges, water supply systems, dairies, food storage and essential war industries; operate report center and record progress of service restoration; obtain meteorological data; handle all eng. details. (6) *Supplies and Transportation:* Procure and issue all materials, tools, equip., vehicles and transportation. (7) *Personnel:* Procure and distribute emergency personnel without customary interdepartmental formalities; conduct accident prevention and investigation and supply medical aid. (8) *Dispatching Labor, Supplies and Transportation:* Contact unit between operating departments and emergency organization. (9) *Affected Operating Depts.:* Regarded as major units of emergency organization; supts. considered as coordinators; supplementary emergency workers placed under direction of Operating Dept. supts.—*H. J. Chapton.*

Regional Development of the Missouri Basin. Harry W. Bashore. Civ. Eng. **14:** 461 (Nov. '44). Bur. of Reclamation has proposed to Congress plan for development of Missouri Basin to provide water for irrigation, power production, and flood control. When 90 multiple-purpose reservoirs with capac. of 63 mil. acre-ft. completed, uniform flow for navigation purposes in lower river will be provided. Estd. that 4,760,400 acres of new land may be placed under irrigation, and irrigation supply of 547,304 acres now inadequately watered will be supplemented. Author ests. that about 250,000 man-yr. of employment can be provided by this general project plan during early part of postwar period. He suggests that crop values will be increased by more than **$168,000,000** annually, and that other benefits should total **$38,000,000** annually. Held that general economic improvement that would be realized in area with completion of plans would support 650,000 addnl. people.—*P.H.E.A.*